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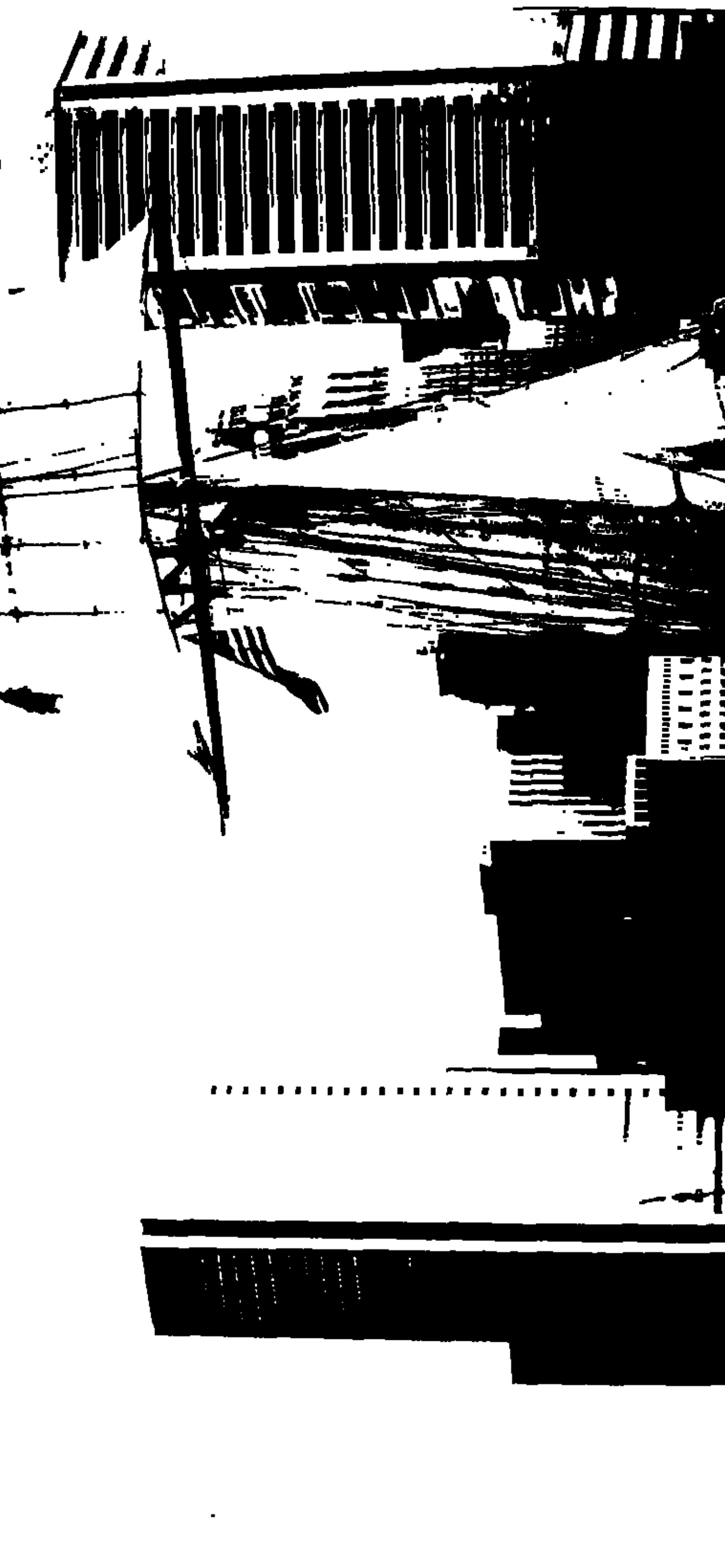

EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION VOL. 62, NO. 14, PAGES 137-152 APRIL 7, 1981

Oceanography

4711 Circulation
SURFACE CURRENTS IN THE CARIBBEAN SEA AS DEDUCED FROM LAGRANGIAN OBSERVATIONS
R. Molinari (NOAA, Atlantic Oceanographic and Meteorological Laboratories, 15 Rickenbacker Causeway, Miami, Florida 33149), M. Spillane, I. Brooks, D. Atwood and C. Duckett

The results of a satellite tracked drifting buoy experiment conducted in the Caribbean Sea from October, 1975 through June, 1976 are presented. The buoy trajectories suggest that the Aves Rise, Beata Ridge and Nicaraguan Rise are regions where considerable mesoscale variability occurs in the surface flow. The variability is in the form of current deflections; small diameter eddies ranging in size from 20 km to 100 km; large amplitude meanders, with amplitudes greater than 150 km; and large diameter eddies, with diameters greater than 200 km which form on and near these Rises and Ridges. In the central Caribbean, where the topographic relief is not as dramatic, the flow is predominantly zonal. Intensifications in the surface flow occur off the coast of Colombia, south of the Nicaraguan Rise and south of the Yucatan Strait. (Caribbean Sea, surface currents, topographic effects).
J. Geophys. Res., Green, Paper 1C0355

4715 Circulation
SYNOPTIC THERMAL FRONTS IN THE MID-LATITUDE NORTH PACIFIC 1976-78
E.R. Levine (Code 3635, Naval Underwater Systems Center, Newport, RI 02840)
W.B. White (NORPAX A-030, Scripps Institution of Oceanography, University of California, San Diego, CA 92037)

Temperature data obtained from June 1976 - May 1978 in the TRANSPAC ships-of-opportunity XBT program have been used to examine the large-scale evolution of synoptic thermal fronts from 165°E to 135°W, from 30°-50°N in the mid-latitude North Pacific on a 2° latitude by 5° longitude grid. These results were referenced to a climatology computed from all XBT data collected in the region from 1968-76. The primary indicator of frontal strength and position was the zonal continuity of the modulus of horizontal temperature gradient in the upper 300m. Over the two year period, the Subarctic Front was observed as a quasi-zonal coherent feature, ranging in latitude between 38°-46°N, strongest at the sea surface, decreasing in strength toward the east. This front is found to have had two realizations, a northern one dominant in winter-spring between 42°-46°N and a southern one dominant in summer-fall between 35°-42°N. Generally, these frontal realizations were vertically coherent with depth. The transition from the southern front to the northern front occurred in either November or December of both years, while the transition from the northern front to the southern front took place in either March or April. In winter-spring, there existed considerable overlap of the existence of these two fronts; however, in summer-fall, the northern front was not observed. The northern front had a tendency to be displaced southward 2-4° through the winter-spring period, while the southern front had no consistent tendency over the two years. At depth, the strength of these fronts shows no significant variability over the two year period and the two fronts are comparable in strength. Two other thermal fronts were observed intermittently, i.e., the Subtropical Front in the eastern part of the region between 30°-36°N and the Kuroshio Extension Front in the western part of the region along approximately 36°N. These fronts were observed to form transient links or filaments with both realizations of the Subarctic Front. (Ocean fronts, temperature, ships-of-opportunity).
J. Geophys. Res., Green, Paper 1C0429

4713 Circulation
A SHALLOW NORTHEASTWARD CURRENT IN THE NORTH PACIFIC
K. Kenyon (Scripps Institution of Oceanography, A-030, La Jolla, California 92093)

A permanent large-scale longitudinal maximum of sea surface temperature at mid-latitudes in the eastern North Pacific is explained by a permanent circulation. One part of the circulation consists of a northeastward current near the surface, which extends diagonally from low latitudes on the western side to mid-latitudes on the eastern side of the basin, and a southwestward return flow on either side and underneath the northeastward current. The other part of the circulation consists of mid-latitude eastward and low latitude westward surface currents. The complete circulation is driven by the wind and by the sun, and it conserves mass and transports heat and eastward angular momentum poleward, as required of the ocean. The seasonal east-west movement of the longitudinal temperature maximum is explained by the north-south movement of the diagonal circulation, which follows the seasonal movements of the sun and wind systems. Seasonal variations in the complete circulation are consistent with the balance of mass, heat, and eastward angular momentum being satisfied throughout the seasonal cycle. (Large-scale circulation, heat balance, angular momentum balance, surface temperature).
J. Geophys. Res., Green, Paper 1C0426

4720 Distributions and water masses
FINESTRUCTURE IN THE CIRCUMPOLAR DEEP WATER
Daniel T. Georgi (Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA)

Volumetric analysis is used to quantify the observed changes in the Circumpolar Deep Water (CDW) potential temperature/salinity relationship along the axis of the Antarctic Circumpolar Current. Marked differences in the CDW potential temperature/salinity properties are found in the South Atlantic. However, the vertical density distribution is not significantly affected: the volume of water in the deep water density class intervals remains unchanged. Lateral mixing with the warmer and saltier North Atlantic Deep Waters (NADW) and the colder and fresher Antarctic deep waters appears responsible for this change.

Thermohaline finestructure, temperature and salinity inversions, has been observed on continuous salinity-temperature-depth soundings in much of the South Atlantic and is presumably the signature of this lateral mixing. This finestructure (of non-internal wave origin) is particularly evident in the southwestern Argentine Basin, where .5°C temperature inversions with 50 to 200 m vertical scales are found at the depth of the NADW/CDW confluence, between 1500 and 2300 m. To quantify the intensity of the finestructure the temperature-gradient variance in the 32 to 256 m vertical wavelength band is calculated for data from the southwest Argentine Basin, the Drake Passage, Scotia Sea, the Central and Eastern Atlantic and the Southwest Indian Ocean. The largest variance levels occur in the Argentine Basin, the smallest in the Drake Passage, while those in the Central Atlantic are intermediate.

The temperature-gradient variance data from the Argentine Basin is then used to estimate the lateral heat flux in the NADW/CDW confluence with a statistical model due to Joyce (1977). The calculated quantities are small; the lateral heat flux is of order 4×10^{-4} °C m s^{-1} and the lateral diffusivity of order 40 $m^2 s^{-1}$. (Circumpolar deep water, finestructure, heat flux).
J. Geophys. Res., Green, Paper 1C0424

4765 Surface waves, tides and sea level
INFRAGRAVITY ENERGY IN THE SURF ZONE
R. Holman (Oregon State University, Corvallis, Oregon, 97331)

Time series of velocity spectra have been obtained within the surf zone on Martinique Beach, Nova Scotia at different stages of the tide and for varying incident wave conditions. The spectra show significant structure, in the form of peaks and valleys, in the infragravity band (.005-.05 hz) but the frequencies of the features vary somewhat with the stage of the tide and are not consistent between instruments. Analysis is carried out in terms of a spectral transformation (the energy spectrum which would be observed at an offshore instrument if the shoreline amplitude spectrum was white with unit spectral energy density). The transformation duplicates the major spectral features in the infragravity band, indicating that the equivalent shoreline amplitude spectrum is relatively smooth (slightly blue) and that the observed structure does not in fact represent any real physical process. The match of transformation and data also implies that the onshore component of infragravity energy is predominantly associated with free waves, not forced oscillations. The longshore velocity spectra fail to show the same wave-associated spectral structure in the infragravity band, implying that forced oscillations are dominant. The wave energy seen in the onshore velocity spectra could then be explained in terms of standing incident waves or by the superposition of many edge wave modes including high modes. Consideration of edge wave dynamics indicates that the latter case might be expected on east coast (of North America) beaches where Atlantic incident swell typically show a moderate directional spread. Comparison of infragravity energy during high and low incident conditions shows that infragravity waves tend to become dominant during storms. However, this observation is from data taken within the surf zone where increases in incident amplitude are limited by the breaking process. There is reason to believe that the opposite observation might have been made if the data had compared more representative variables such as the offshore incident amplitude and the shoreline edge wave amplitude.
J. Geophys. Res., Green, Paper 1C0314

4780 Underwater Sound
SCATTERING FROM VOLUME VARIABILITY
L. Goodman and K. A. Kemp

Acoustic scattering cross sections for medium fluctuations have been derived from the fundamental wave equation. The effect of a finite scattering volume has been analyzed. Fluid velocity fluctuations can be shown to produce no backscatter at scattering angle $\theta = 180°$, independent of the statistical form of the velocity field. Scattering from sound speed fluctuations for the atmospheric and oceanic cases is compared. Using a cylindrically symmetric form about the vertical direction for temperature fluctuations, explicit expressions for the scattering cross sections are obtained. These results depend strongly on the parameter α, the ratio of the vertical length scale of the temperature variability to the horizontal length scale. For a typical echo sounder operating at 20 kHz, scattering strengths based on observed values of temperature microstructure are of order -120 dB if isotropy is assumed ($\alpha = 1$). For the layered case, where the horizontal scale of the variability is larger than the horizontal dimension of the scattering volume, scattering strengths are of order -70dB. These results can be extended to other frequencies provided the medium variability spectrum is known.
J. Geophys. Res., Green, Paper 80C1691

The Great Solar Eruption of May 24, 1979

Neil R. Sheeley, Jr., D. J. Michels, R. A. Howard, and M. J. Koomen

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Naval Research Laboratory
Washington, D.C.

The sequence of images on today's cover of *Eos* shows the most spectacular solar mass ejection observed to date with the Naval Research Laboratory's Earth-orbiting coronagraph. Preceded by a loop-shaped coronal structure, an enormous eruptive prominence is visible both expanding and moving outward across the coronagraph's 2.5–10.0-R_S annular field of view. As it left the field, the prominence dwarfed the sun itself, whose size and location are indicated by the small white disk in the lower-right photograph.

The prominence can be recognized by its characteristic structural detail and by the fact that its relatively unpolarized radiation is not blocked by the polarization-analyzing rings that are faintly visible at 5 R_S and 8 R_S against the coronal background. The Hα 6563-Å line of neutral hydrogen is the principal prominence emission line in the coronagraph's 4000–7000-Å spectral bandpass. On the other hand, the strongly polarized coronal radiation is continuum emission originating at the occulted solar disk and Thomson scattered by coronal electrons in the 2.5–10.0-R_S field of view. Both the prominence and the expanding coronal 'loop' have been enhanced in our cover photograph by subtracting a preevent image from each picture.

When such prominences are observed prior to their eruption, they reveal a wealth of fine structure similar to that shown here, but with a spatial scale that is more than an order of magnitude smaller. This fine structure has made it difficult to determine the physical properties of even quiescent prominences, despite numerous attempts to do so over the years. The composition of a prominence is believed to be similar to that of the sun itself: 90% hydrogen, 9% helium, and trace amounts of oxygen, carbon, nitrogen, and the less abundant elements. The hydrogen is estimated to be from 50% to 90% ionized, and the resulting electrons have densities and temperatures of approximately 10^{10} cm^{-3} and 10^4 K, respectively. In contrast, the fully ionized coronal plasma has an electron density on the order of 10^8 cm^{-3} and a temperature of approximately 10^6 K near the sun's surface.

These estimates have often raised the question of how a relatively cool, dense prominence can persist in the hot corona for several weeks to months prior to its eruption. The usual response is that the prominence is wrapped somehow by a protective magnetic field which shields it from the hot and highly ionized corona. Indeed, observations of the sun's surface magnetic fields and their associated atmospheric tracers do point to the possible existence of magnetic fields twisted somehow around or through prominences. Despite this supposed shielding, the individual prominence structures seem to have thermal skin depths within which the electron temperature drops from 10^6 K to 10^4 K. This idea is supported by the fact that a prominence looks remarkably unchanged when observed in emission lines that are formed over a wide range of temperatures from approximately 10^4 K to 0.5×10^6 K. Evidently the large-scale appearance of the prominence is relatively insensitive to whether the radiation is from the 'outer skins' or 'inner depths' of the unresolved prominence fine structures.

If one uses the sequence of images to trace the outward motion of the May 24 eruptive prominence, he finds a radial velocity (in the plane of the sky) that quickly accelerates from 350 km/s at 2.7 R_S to a nearly constant value of 700 km/s between 3 R_S and 10 R_S. Thus, in this sequence, the prominence motion rapidly exceeded the sun's escape velocity, which is 618 km/s at the surface and falls as the square root of the radial distance (376 km/s at 2.7 R_S and 195 km/s at 10 R_S. Furthermore, this prominence motion was highly supersonic, compared to the 170 km/s proton thermal speed of the 10^6 K coronal plasma. This fact raises the presently unresolved question of whether the preceding coronal 'loop' should be interpreted as an outward-propagating shock wave, an expansion of overlying magnetic flux loops, or both.

Perhaps the most notable aspect of the May 24 eruption is the fact that the prominence maintained its overall shape while increasing its linear dimensions by an order of magnitude. Except for the large scale difference, the structure looked just as much like a prominence at 5–10 R_S in these relatively low-resolution (1.25 arc min) coronal images as it did at 1 R_S in much higher resolution (2 arc sec) ground-based Hα images obtained prior to the eruption. Evidently, this shape preservation reflects a systematic large-scale motion such as would be produced by a mass-flux-conserving 'explosion' or by a magnetic expansion. In comparison, a diffusive expansion caused by thermal motions or by random motions of the prominence's initial fine structures would have blurred out the prominence's shape in an expansion of this magnitude. Moreover, the 17 km/s proton thermal speed of a 10^4 K prominence is much too slow to have produced the observed 100 km/s widening and 400 km/s lengthening of the prominence.

As in many other eruptive prominence events, no associated solar flare or large X ray burst was observed from Earth, despite the availability of suitable observations. However, at the time of its eruption the prominence was located 2 days behind the sun's east limb, where an associated flare or X ray burst might well have been hidden. Indeed, when solar rotation carried this longitude around the east limb into view, one could see that a large new magnetic region had emerged near the former prominence's previously quiet location. One would expect this flux emergence to have disturbed the prominence, regardless of whether it may also have produced a solar flare.

Finally, we mention that this Naval Research Laboratory coronagraph operated routinely on the Department of Defense Space Test Program Satellite P78-1 during 1979 and 1980, and continues to do so in 1981. As we process these data and compare them with other observations during this era of high sunspot activity, we hope to understand these eruptions and their influence on the interplanetary medium.

Acknowledgements

The NRL coronagraph was launched on the P78-1 spacecraft under the auspices of the Department of Defense Space Test Program. We are grateful to STP, NASA, and the Office of Naval Research for their support in this endeavor. We are also grateful to D. Roberts, F. Harlow, R. Chalmson, and R. Seal, who provided engineering and technical support, and to T. Rohlfs and W. Funk, who have assisted with the data reduction. In the preparation of this article we have benefited from conversations with several of our scientific colleagues, both at NRL and elsewhere.

The four authors of this article are research physicists at the E. O. Hulburt Center for Space Research of the Naval Research Laboratory. *N. R. Sheeley, Jr.*, received his education at the California Institute of Technology. His current interests are in the structure and evolution of solar magnetic fields and their extension into interplanetary space. *D. J. Michels*, principal investigator of the coronagraph experiment, was educated at St. Peter's College, Fordham University, and the Catholic University of America. He is interested in the solar corona as a source of the solar wind and a driver of geomagnetic anomalies. *R. A. Howard* was educated at the University of Maryland. He is responsible for the data system and the automated observing program that produced the coronal images accompanying the article. His research interests center on the dynamics of coronal structures and their extension into the solar wind. *M. J. Koomen* designed the first spaceborne coronagraph for flight in an Aerobee rocket in 1963. From that experiment grew a series of successful designs for rocket-borne and orbiting coronagraphs (including the present instrument), which produced the first evidence that showed rapid evolution of coronal structures and the first optical observations of coronal mass ejections. Educated at the University of Rochester, his research interests include the outer solar corona, precision radiometry, and space optics.

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Cover. This series of images shows the changes in the sun's outer corona that are associated with a very large eruptive prominence. Surrounded by a bright coronal loop, the prominence expanded in size by an order of magnitude as it traversed the coronagraph's 2.5–10-R_S field of view at approximately 700 km/s. The prominence can be distinguished from the corona both by its characteristic finer detail and by the fact that its intensity was not reduced by the polarization analyzer rings that are faintly visible against the corona at 5 R_S and 8 R_S. The 4000–7000-Å bandpass shows the corona as strongly polarized Thomson-scattered photospheric emission and the prominence as relatively unpolarized Hα 6563-Å line emission. In the lower right image, the white area indicates the size of the solar disk, and the scale is marked in solar radii. The Naval Research Laboratory white light coronagraph has been operating successfully on the DOD satellite P78-1 since March 1979. (Naval Research Laboratory photograph courtesy R. A. Howard, M. J. Koomen, D. J. Michels, and N. R. Sheeley, Jr.)

News

Rough Seas for Ocean Drilling

Federal funding for the Ocean Margin Drilling Program (OMD) may be in jeopardy in Congress. The original budget request by the Carter administration for fiscal year 1982 was $16 million (*Eos*, Mar. 24, 1981). The Reagan administration Office of Management and Budget recommended reduction to a level of $12 million, but now the program could be scrubbed altogether. Recent action taken by the House Subcommittee on Science, Research, and Technology has included cutting the OMD program from the National Science Foundation FY 1982 budget. This action is sponsored by a Democratic House majority.

Representative A. Ertel (D., Penn.) raised strong objections to the program's being supported jointly by the federal government and industry, in this case petroleum companies. In an effort to get the program underway last year, 10 oil companies were asked to support the program financially and technically. The federal government was to pay for only half the costs. Ertel interpreted the joint effort as 'a subsidy of the oil companies,' and 'not a science project.' He has stated to the effect that the OMD program was one of petroleum exploration.

Actually, the OMD program was created as a scientific drilling program to explore the geology of the continental slope. There is fundamental science to be gained on the crucial boundary between oceanic and continental plates. True, the oil companies would like to find oil on the slopes—so would many other interests. But, presently there is precious little scientific data available on the ocean margins. The oil companies will need an extensive base before exploration can ever begin. The rules agreed upon are that drilling is not to be 'on structure,' i.e., drilling is not to be located on petroleum or gas locations. The locations are to be scientifically located.

Technological advances for the OMD program are to be manifold. Drilling at depths in excess of 4000 km of water has not been done before, much less with the required blowout protection and riser mechanism. Development of those techniques will take some years. The spinoff should be of value to industry, government, and research interests.

The last word on the OMD program in the House of Representatives is not yet 'cast in concrete.' The NSF budget awaits full committee approval and appropriations. Other portions of the budget that had been reduced sharply by OMB have now been increased by House Democrats, while the Ocean Margin Drilling Program was being cut The outlook for the program does not look bright. Further, passage of the NSF budget through the Republican-dominated Senate may be difficult as well. The mood to cut the program may dominate if support is not established —*PMB*

Little Solar Impact From Planets' Alignment

Contrary to some projections, planetary alignments of the type that have begun recently (when the sun, Venus, Earth, Jupiter, and Saturn move into almost perfect alignment) should have no perceptible effect on solar flare activity. Some researchers have postulated that the increased gravitational attraction exerted on the sun by the aligned planets could produce massive eruptions near sunspots. The radiation and particles directed earthward by the sun, according to this hypothesis, would change the atmosphere in a way that would slow the earth's rotation; and this change in rotation rate would cause the large plates which constitute the earth's crust to grind together more vigorously and cause major earthquakes. Because Jupiter is the largest of the planets, and so exerts the most gravitational attraction, this geophysical domino theory is sometimes referred to as the Jupiter Effect. But, at least at the solar end of this theory, one would not expect much change in solar activity from planetary alignments of this type.

'We may have major solar flares occuring at about the same time as this planetary alignment,' explains Patrick McIntosh, of the Space Environment Laboratory in Boulder, Colo., 'but they should have little or nothing to do with the fact that the planets are aligned.' This is not to say that such alignments produce no perceptible effect, he notes, but that the effect is a very small one. 'There is some evidence that planetary positions may have some modulating influence on sunspot number. But this apparent connection seems to pertain only to variations in sunspot number, not to the magnitude of solar activity. Certainly, planetary alignment should not be considered a primary mechanism behind solar flares.'

The term, sunspot number, is an index developed about a century ago that counts all sunspots, then adds 10 times the number of sunspot groups—thus if there were a single sunspot on the sun, the sunspot number would be 1 plus 10 times 1, or 11. 'We find that sunspot number does not correlate well with the incidence of powerful flares,' McIntosh says. 'For example, we've had a rather high sunspot count for this present 11-year cycle of sunspot activity, but we've had relatively few large flares. The spots we've seen most are relatively small, relatively stable ones. Flare activity favors the larger, more complex sunspots. The most powerful flares in the last solar cycle did not occur when we were at our peak sunspot number.' McIntosh acknowledges that the planets do produce tides on the sun by the sweep of their gravitational fields but notes that the effect is quite small. 'Solar tides caused by the planets' gravitation attraction are measured in millimeters,' he says, 'compared to the rather large tides caused by the moon and sun in our ocean and atmosphere. In fact, most solar astronomers would say the sun barely knows the planets are out there.'

(News cont. on page 154)

(News cont. from page 153)

The planetary alignment that began March 25 and evolved through April 7 placed Saturn, Jupiter, Earth, The sun, Venus, and Mars in a rough line, a configuration properly called 'syzygy.' About a year later, they will come into a much rougher conjunction on the same side of the sun. But, according to McIntosh, this month's syzygy places the planets much closer to a common line, and would be the most favorable configuration for the so-called Jupiter Effect to be felt.—*PMB* ⊠

Voyager Status Report

As the Voyager 1 spacecraft speeds away from Saturn, it leaves in its wake a plethora of data for the team scientists to puzzle over. Although they still grapple with data from the November 12 encounter, the team scientists have put together a report of their early findings. This report, published in the April 10 issue of *Science*, was recently summarized at NASA headquarters by representatives of the Voyager team.

The analyzed data confirm some earlier hypotheses (*Eos*, Dec. 2, 1980, p. 1201) and necessitate reshaping of others. For example, the 'spokes' in the *B* ring are probably explainable by Keplerian laws, or so it was hypothesized immediately after the Saturn flyby; magnetic forces also may be affecting the ring. But Titan was found not to be the largest satellite in the solar system.

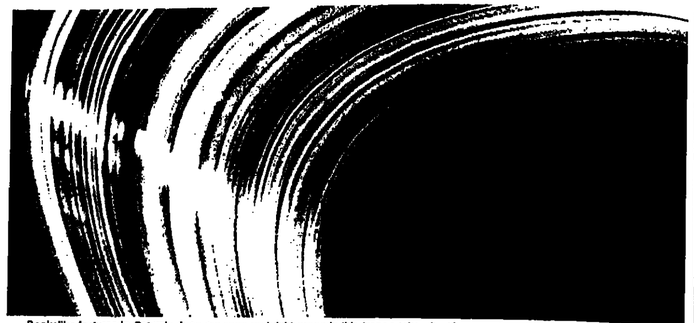
Saturn's rings, though complex, do not counter known laws of physics, explained Bradford Smith, Voyager imaging team leader. The problem, however, is in applying the known laws. The apparent 'braiding' of strands in the outermost *F* ring remains a mystery, as does the mechanism by which the myriad rings and ringlets remain discrete. The satellite resonance theory proposed by Peter Goldreich at JPL and Scott Tremaine at Princeton University seems to hold true for many of the known satellites. However, the *C* ring's regularly spaced ringlets show no clear association with satellite resonances, Smith added.

Titan's atmospheric haze previously prevented accurate measurement of the satellite's size. Edward C. Stone, Voyager project scientist, reports that Titan's radius is 2570 km, about the distance between Dallas and Boston. The temperature at Titan's surface is 93° K; the pressure is 1.6 atmospheres, Stone said. Methane's triple point—the temperature at which it can exist as a solid, liquid, and gas—is 91° K. Therefore, if the atmosphere contained 5% methane, Stone explained, a methane ice cloud would form 5–10 km above Titan's surface. The amount of methane in Titan's atmosphere is uncertain, however.

Smith reported that the barely visible brightness difference between Titan's northern and southern hemispheres may be related to the effects of the solstice. Titan shows a phase lag of 90°, or one-quarter of a year, Smith explained. Therefore, at the equinox the effects of the solstice would be visible. Titan is just entering equinox now.

Heavy cratering on many of Saturn's satellites may be the result of two bombardment periods, the scientists believe. Most of the large craters (20 to 100 km) were formed during the first period, according to the hypothesis. Smoothing of the surfaces of the larger satellites was accomplished with tectonic activity, perhaps driven by radionuclides. The second bombardment period produced smaller craters. Material spewed into the Saturnian system during the first bombardment may have been responsible for the second 'bombing.' One problem with this model, Smith said, is that scientists are unsure what the driving force was that smoothed Tethys' surface, since the satellite is almost entirely ice. Another problem is explaining the unblemished complexion of Enceladas.

Soon Voyager 1's sister craft, Voyager 2, will take the spotlight. Scheduled for its Saturn encounter on August 26, Voyager 2 will attempt to fill in gaps of information left by Voyager 1. Specifically, the craft will take a closer look at Enceladas, the satellite Hyperion, and the complex ring system. JPL's Davis expects the programing of the experiment sequence to be completed by late May or early June. He gave both craft a clean bill of health: 'Things are going according to plan.'—*BTR* ⊠

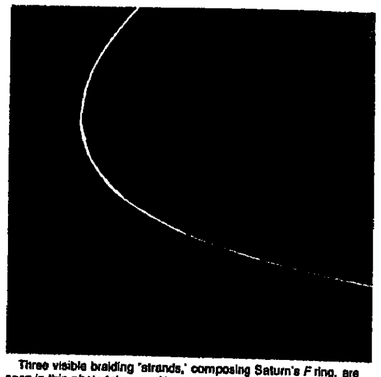


Spokelike features in Saturn's rings are seen as bright areas in this image taken by Voyager 1 on November 13, 1980, when the spacecraft was 936,000 km from the planet's cloud tops. Where sunlight forward-scatters on the rings, the spokes appear bright; the same features appear dark in backscattered light. In this view, the concentric structure in the *B* ring increases contrast and accentuates hundreds of light and dark ringlets. (Photo courtesy of NASA).

Status of Voyager Spacecraft, April 1, 1981

	Voyager 1	Voyager 2
Spacecraft distance from Earth, km	1,381,718,789	1,145,473,428
Spacecraft distance to Saturn, km	------	138,129,314
Spacecraft distance traveled since launch, km	2,430,281,184	2,088,807,260
Spacecraft velocity relative to Earth, km/s	20.8	22.3
Spacecraft velocity relative to sun, km/s	21.2	16.0
Date of Saturn encounter (closest approach)	Nov. 12, 1980	Aug. 26, 1981

Source: NASA



Three visible braiding 'strands,' composing Saturn's *F* ring, are seen in this photo taken on November 12, 1980. The *F* ring is bounded by two 'shepherding' satellites discovered by Voyager 1. Scientists believe the gravitational effects of the two satellites may confine particles in the *F* ring to a narrow band. In addition, the braiding structure of the ring may be a result of the eccentric motion of the two small satellites. The *A* ring and the Encke Division are seen to the upper right. (Photo courtesy of NASA).

IIASA Energy Study Unveiled

Meeting the energy needs of the world in 2030, when the projected population will be 8 billion, can be done, but not without international cooperation, a mix of energy technologies, and an understanding of the dependence of resources and use. That's the optimistic conclusion of the 7-year global energy study by the International Institute for Applied Systems Analysis (IIASA).

Results of the international study were published last month in two volumes. *Energy in a Finite World: Paths to a Sustainable Future* outlines the strategies IIASA believes will meet energy needs; its companion volume *Energy in a Finite World: A Global Systems Analysis* presents the study's complete technical findings.

According to Wolf Häfele, leader of the Energy Systems Program Group, IIASA's conclusions are similar to those reached by the 4-year study done by the National Academy of Sciences' Committee on Nuclear and Alternative Energy Systems (CONAES) (*Eos*, Feb. 19, 1980, p.90). However, the results differ in the types of transition periods to technology mixes. While CONAES envisions one transition period (1985–2010), IIASA sees two. The first will last through 2030, and the second transition will occur through the end of the 21st century.

Global Primary Energy by Source, Two Supply Scenarios, 1975–2030 (TWyr/yr)[a]

Primary Source[b]	Base Year 1975	High Scenario 2000	High Scenario 2030	Low Scenario 2000	Low Scenario 2030
Oil	3.83	5.89	6.83	4.75	5.02
Gas	1.51	3.11	5.97	2.53	3.47
Coal	2.26	4.94	11.98	3.92	8.45
Light water reactor	0.12	1.70	3.21	1.27	1.89
Fast breeder reactor	0	0.04	4.88	0.02	3.28
Hydroelectricity	0.50	0.83	1.46	0.83	1.46
Solar[c]	0	0.10	0.49	0.09	0.30
Other[d]	0	0.22	0.81	0.17	0.52
Total[e]	8.21	16.84	35.65	13.59	22.39

[a]Terrawatt-year per year; 1 TWyr/yr = 30 × 10^{15} BTU
[b]Primary fuels production or primary fuels as inputs to conversion or refining processes—for example, coal used to make synthetic liquid fuel is counted in coal figures.
[c]Includes mostly 'soft' solar—individual rooftop collectors—and also small amounts of centralized solar electricity.
[d]'Other' includes biogas, geothermal, and commercial wood use.
[e]Columns may not sum to totals because of rounding.
Source: *Energy in a Finite World: Paths to A Sustainable Future*

During the first period, the globe will continue to consume fossil fuels, but the fuels will become increasingly dirty. The major transition to renewables—solar, geothermal, ocean currents, wind power, hydropower, etc.—will come late in the next century, according to the IIASA report.

The study engaged the help of 140 scientists from 20 countries, a first for this type of study. IIASA stresses the global nature of the energy problem: 'While the problem transcends national borders, policy analyses tend to follow suit only selectively. . . . But such provincialism can only lead to dangerously misguided national policies,' the report tries in the analysis, but grouped them into seven regions categorized by natural energy resources and economic structure. Geographic proximity was not necessarily a consideration. For example, one region encompasses Western Europe, Australia, Israel, Japan, New Zealand, and South Africa. These have developed market economies, but are poorer in resources than other developed regions.

The initial, 50-year transition was chosen for four reasons that allow for technological and social change. First, by the year 2030, IIASA estimates that the world population will double from its present 4 billion—the steepest increase ever. Second, 50 years is approximately two complete life cycles for power plants and energy facilities. Third, the time period represents two human generations and the accompanying social changes. Last, the time frame allows for market penetration of advanced energy technologies. 'To expect a transition to a sustainable worldwide energy system within anything much less than 50 years would be to flagrantly ignore history,' according to IIASA.

Increasingly dirty fossil fuels will be used through the first transition period, the IIASA report said. Global dependence on synthetic fuels and unconventional oils will increase through 2030. Approximately 60% of the energy supplied in 2030 will be from dirty fossil fuels, Häfele said. 'There is no way of partly escaping the dirty route,' he added. The report states that sometime around 2000, large-scale coal liquefaction will become necessary, although Häfele could not define the process most likely to be used. Joining liquefaction in 2000 will be fast-breeder reactors, in IIASA's picture.

Two Benchmark Scenarios

IIASA developed two benchmark scenarios based on the level of worldwide energy demand—'high' and 'low.' As illustrated in the accompanying table, the high scenario relies mostly on coal-fueled energy in 2030, while the low scenario relies almost equally on oil as on coal. Magnetohydrodynamics and fusion energy will not significantly contribute to global energy by 2030.

Three alternative cases also were presented: a nuclear moratorium case, an enhanced nuclear case, and zero-per-capita growth rate. In the last, global energy use is restricted to the present rate and requires extreme conservation measures.

Given the world situation and the history of noncooperation among nations, is the optimism expressed in the report justified? Although Häfele said he agrees with the bottom line of the report—that energy needs can be met with world resources—he is less optimistic about the needs being met. He pointed to an increasing dichotomy between the perception of reality and reality itself. The political situation, economics, and the cold war could block the securing of energy to meet global demands.—*BTR* ⊠

Petroleum Data Available

New geological and geophysical data associated with certain regions in the National Petroleum Reserve in Alaska (NPRA) are available to the public from the National Geophysical and Solar-Terrestrial Data Center.

These data were collected and processed by several companies under contract to the U. S. Geological Survey. Purpose of the data collection was to evaluate the petroleum potential of portions of the NPRA.

Included in the available data are seismic data, well logs, and gravity data through September 30, 1980.

Inquiries on the filers listed below should be addressed to National Geophysical and Solar-Terrestrial Data Center, NOAA/EDIS (D62), 325 Broadway, Boulder, CO 80303 (telephone: 303/497-6826).

Filer Number	Subject
1981 (SE-E)	NPRA 10 Well Logs and Auxiliary Data (1979–1980)
1981 (SE-D)	NPRA Seismic Data (FY 1980)
1980 (SE-NN)	NPRA Gravity Data (1974–1980)
1980 (SE-MM)	NPRA Geological Data (FY 1979)
1980 (SE-LL)	NPRA Seismic Data (FY 1979)
1980 (SE-HH)	NPRA Common Depth Point (CDP) Field Tapes ⊠

NRC Associateship Survey

The National Research Council (NRC) wants to locate its former research associates and visiting scientists research associates to verify official records. The NRC also hopes to assess the effects of the research associateship programs on career development.

All associates should send their correct mailing address, dates of tenure, and the name of the laboratory where the associateship was pursued to F. A. Crump, Assistant to the Director of Associateships, National Research Council, 2101 Constitution Avenue, Washington, D.C. 20418. ⊠

Geophysicists

John S. Dickey, Jr., has been appointed chairman of the geology department and Jessie Page Heroy Professor of Geology at Syracuse University. He will leave his post as director of the petrology/geochemistry program in the Division of Earth Sciences at the National Science Foundation to begin his duties at the university on July 1.

New Publications

China Science and Technology Abstracts

International Science and Technology Information Service, Hong Kong, $5.00 per issue.

Reviewed by Carl Kisslinger

The obvious purpose of a review of a new abstract journal is to bring it to the attention of potential users and offer some idea of the scope of the contents. I was sent Volume I, Number 2, October 1980, and, if it is typical, the publication will be of definite value to many readers of *Eos*. The stated purpose of the journal is 'to give them (i.e., scientists outside of China who cannot read the Chinese language) an outline of the latest development of science and technology in China.' From the sample I examined, the journal achieves this purpose admirably. Sixty-nine 'highly reputed Chinese periodicals' provided the material for the particular issue. The claim that each issue will contain about 500 abstracts seems exaggerated, since many of the entries are titles only. However, even these serve to give a feeling for the main lines of current research interests, and many of the real abstracts are sufficiently long and detailed to be useful as sources on research results (though without the supporting data).

The abstracts are classified under major disciplinary headings, with appropriate subheadings; mathematics, astronomy, physics, chemistry, earth science, engineering physics, mechanical engineering, electrical and electronic engineering, architecture and civil engineering, transportation engineering, technology of industrial chemicals, and other branches of engineering. The classification of the papers under these headings is fairly arbitrary. Material of interest to various sections of AGU is scattered throughout, but most relevant material is naturally found under astronomy, physics, and earth science (an entry on acupuncture signals in cerebral cortex under "astronomy" is a rather startling slip). The earth science section is further divided by topics ranging from geodesy and geophysics, through geodynamics (internal and external), to oceanography, hydrography, meteorology, petrology and geochemistry, and economic geology.

China Science and Technology Abstracts is especially attractive as an information source because the publisher offers copies of the original articles ($0.50 per page), English translations ($10 per 100 English words), and extended English abstracts (roughly one-tenth the original length, at $15 per 100 English words). The quality of the English language in the abstracts I read is quite good so that one can be optimistic that the translations offered will be satisfactory with regard to readability.

Carl Kisslinger is with the Cooperative Institute for Research in Environmental Sciences, University of Colorado at Boulder, Boulder, Colorado.

New Listings

Items listed in New Publications can be ordered directly from the publisher; they are not available through AGU.

Advanced Chemical Methods for Soil and Clay Minerals Research, J. W. Stucki, W. L. Banwart (Eds.), D. Reidel, Hingham, Mass., viii + 477 pp., 1980, $58.00.

Archean Greenstone Belts, Developments in Precambrian Geology 3, K. C. Condie, Elsevier, New York, 434 pp., 1981, $122.00.

A Climatologic and Oceanographic Analysis of the Georges Bank Region of the Outer Continental Shelf, Final Report to the Bureau of Land Management, U.S. Department of the Interior, U.S. Department of Commerce, NOAA, x + 290 pp., 1980.

The Primordial Bond: Exploring Connections Between Man and Nature Through the Humanities and Sciences, S. H. Schneider and L. Morton, Plenum, New York, xii + 324 pp., 1981, $15.95.

United States Earthquakes, 1978, C. W. Stover and C. A. von Hake (Eds.), U.S. Department of the Interior and U.S. Department of Commerce, Boulder, Colo. vii + 112 pp., 1980.

Classified

EOS offers classified space for Positions Available, Positions Wanted, and Services, Supplies, Courses, and Announcements. There are no discounts or commissions on classified ads. Any type that is not publisher's choice is charged for at display rates. EOS is published weekly on Tuesday. Ads must be received in writing on Monday 1 week prior to the date of the issue required.

Replies to ads with box numbers should be addressed to: Box ——, American Geophysical Union, 2000 Florida Avenue, N.W., Washington, D.C. 20009.

POSITIONS WANTED
Rates per line
1-5 times—$1.00, 6-11 times—$0.75, 12-26 times—$0.55

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STUDENT OPPORTUNITIES
For special rates, query Robin Little, 800-424-2488.

POSITIONS AVAILABLE

Planetary Geologist. Tenure track assistant to associate professor position starting September 1, 1981, or as soon as possible thereafter to teach and conduct research in planetary geologic processes on Earth and other planets. Research should be on understanding the physical processes (for example, impact cratering, volcanism, tectonism) responsible for the origin of planetary surfaces. Applicants must have Ph.D. in planetology, geophysics or geology. Deadline for applications is June 15, 1981. Inquiries to: Paul C. Hess, Chairman, Department of Geological Sciences, Brown University, Providence, RI 02912.

An equal opportunity and affirmative action employer.

Faculty Opening. The Department of Geological Sciences of the State University of New York at Albany invites applications for a tenure track faculty position which will be available from September 1, 1981 at the assistant professor level for a research oriented scientist to join a department with strengths in structural geology, tectonics, geochemistry and petrology. Applications are invited from geologists, geophysicists and geochemists with Ph.D. degrees who feel qualified to complement or augment studies in these fields. Salary will be negotiable. Letters should be addressed to: Professor Kevin Burke, Chairman, Department of Geological Sciences, c/o Personnel Department, State University of New York at Albany, Albany, N.Y., 12222.

SUNY at Albany is an equal opportunity/affirmative action employer. Applications from women, minorities and handicapped are especially welcome.

Two Winter-over Positions in Antarctica. Two positions are available to conduct scientific measurements in Antarctica of the earth's high atmosphere. These persons will winter-over at Siple and South Pole stations in 1982.

One position will be as *engineer-scientist* at Siple Station, Antarctica. The primary responsibilities of this position will be the operation and maintenance of a High Frequency (100 kHz to 30 MHz) vertical incidence radar system and a sophisticated optical experiment conducted by the Lockheed Palo Alto Research Laboratory. The radar system is a 10 kw ionospheric sounder using the latest techniques of RF and digital electronics; real-time control of the transmitter and receiver and initial data processing are handled by two micro-computers which are in turn controlled by a disk-based minicomputer system. Minimum requirements for this position are a B.S., practical experience in digital and analog electronics, and experience with computer software.

The second position will be as a *field engineer* at the South Pole Station, Antarctica. The applicant will be responsible for the operation and maintenance of a variety of upper atmospheric research experiments. The experimental apparatus includes riometers, photometers, an ionosonde, magnetometers and an all-sky camera. Minimum requirements are a B.S. or equivalent practical electronics experience.

The period of employment is expected to run from late summer 1981 to February 1983 (with a possibility of extension depending on available funding); both positions require that the applicant be resident at the South Pole or Siple during the Antarctic winter. Successful applicants will undergo periods of training at Utah State University, Lockheed Research Laboratory, and the University of Maryland.

Applicants should submit a resume and request three letters of reference be sent by 15 May 1981 to F. T. Berkey and J. R. Dugnolli, Center for Atmospheric and Space Sciences, Utah State University, UMC 34, Logan, Utah 84322, Telephone (801) 750-2982.

USU is an equal opportunity employer M/F.

Structural Geologist. The Department of Geophysical Sciences invites applicants for a tenure track structural geology position at the assistant or associate professor level, beginning August 1981, Ph.D. required. Salary commensurate with experience and qualifications.

Departmental equipment includes a digitizer, various geophysics equipment, and a remote sensing laboratory with an edgewise enhancer. The candidate will have the opportunity to substantially add to his or her equipment needs. Present computer facilities include a DEC 10 and IBM 360-44, while PK 3240 system with 16 megabyte capacity is under development.

ODU is a state-supported university serving nearly 15,000 students and is situated within the seventy city Hampton Roads metropolitan area that is nationally known for its historic, recreational, and cultural facilities.

Send vitae, a brief discussion of research interest, and arrange to have three letters of reference by May 1, 1981 to Dr. Dennis A. Darby, Chairman, Department of Geophysical Sciences, Old Dominion University, Norfolk, VA 23508.

An affirmative action/equal opportunity employer.

Director
CIMAS UNIVERSITY OF MIAMI

The University of Miami is searching for a director of its Cooperative Institute for Marine and Atmospheric Studies. CIMAS was established in 1977 by the University of Miami and the Environmental Research Laboratories of the National Oceanic and Atmospheric Administration to serve as a focal point for comprehensive research on specific problems of the ocean and atmosphere.

Present research is concentrated in three areas:

1. Oceanic variability on climatic scales
2. Sediment Dynamics
3. Ecological Modelling

The director should have a national and international scientific reputation in one of these three research areas and take an active interest in each of them.

The successful candidate will also receive an appointment as professor in one of the scientific divisions of the Rosenstiel School of Marine and Atmospheric Science of the University of Miami.

The term of the director of CIMAS shall normally be five years and is renewable.

Applications including a current professional resume and three references, and further information should be sent to Dr. Warren J. Wisby, Chairman of the Search Committee for Director of CIMAS, University of Miami, Rosenstiel School of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, Florida 33149. Nominations and applications desired by June 15, 1981. Position will remain open until filled.

An equal opportunity/affirmative action employer.

Structural Geology/University of Illinois at Champaign-Urbana. The Geology Department is seeking a structural geologist for a tenure-track (assistant professor) faculty position. A Ph.D. is required. Salary open. The successful candidate will be expected to teach advanced undergraduate and graduate courses in structural geology and establish a research program. For equal consideration, applications, including the names of three references, should be sent by August 1, 1981 to Dr. D. E. Anderson, Department of Geology, University of Illinois, 245 Natural History Building, 1301 West Green Street, Urbana, IL 61801. (217) 333-6713

Position to be filled by 1-1-82

The University of Illinois is an affirmative action/equal opportunity employer.

Associate Professor/New Mexico State University. Geophysics at NMSU is an interdisciplinary program between the Department of Physics and the Department of Earth Sciences with an emphasis in exploration geophysics. We are seeking an additional tenure track faculty member with a background in either seismics and seismology or electrical and electromagnetic methods. The successful candidate will be expected to teach upper division and graduate courses, conduct research and to supervise graduate students' thesis and dissertation research in the candidate's area of expertise. The appointee will also be expected to teach freshman and sophomore level courses in either physics or geology.

Minimum qualifications include an earned doctorate in geophysics or a closely related area and demonstrated research capabilities. Teaching experience and a proven ability to secure research funding are desirable but not essential.

The expected salary range for this position is $26,000–$28,000 for the nine-month academic year.

Applications and letters from at least three references should be submitted by May 15, 1981 to either Dr. Russell E. Clemons, Head, Department of Earth Sciences, Box 3AB or Dr. August Miller, Head, Department of Physics, Box 3D, Las Cruces, NM 88003.

New Mexico State University is an affirmative action/equal opportunity employer.

Professor/Chemical Oceanography. The Department of Oceanography of Texas A&M University invites applications for an academic faculty position. The appointment is expected to be made at the level of professor.

Hence, applications are solicited from individuals who have demonstrated scholarship in research and teaching. Outstanding applicants suitable for appointment to academic ranks other than professor will also be considered, but preference will be given to applicants suitable for appointment to the higher ranks.

To apply, or for further information, please contact Professor R. O. Reid, Head, Department of Oceanography, College Station, TX 77843 (713/845-7211).

Texas A&M University is an affirmative action/equal opportunity employer.

Tectonophysics. Seek half-time visiting professor for the academic year 1981–82 to teach course in regional tectonics and seminar of own choosing. Appointment is for half-time for entire academic year or full time for either fall or spring semester. Ph.D. required. Rank and salary negotiable. Inquiries to: Paul C. Hess, Chairman, Department of Geological Sciences, Brown University, Providence, RI 02912. Deadline for applications is May 31, 1981.

An equal opportunity and affirmative action employer.

Professor/Oceanography. The Department of Oceanography of Texas A&M University invites applications for an academic faculty position. The appointment is expected to be made at the level of professor in one of the major sections of the Department—biological oceanography, chemical oceanography, geological and geophysical oceanography, or physical oceanography.

Hence, applications are solicited from individuals who have demonstrated scholarship in research and teaching in any oceanographic subdiscipline. Outstanding applicants suitable for appointment to academic ranks other than professor will also be considered, but preference will be given to applicants suitable for appointment to the higher ranks.

To apply, or for further information, please contact Professor R. O. Reid, Head, Department of Oceanography, College Station, TX 77843 (713/845-7211).

Texas A&M University is an affirmative action/equal opportunity employer.

Exploration Geophysicist/University of Oklahoma. The School of Geology and Geophysics at the University of Oklahoma will hire an experienced exploration geophysicist to fill the Frank and Betty Schultz Professorship, and is seeking nominations and applications for the position. The person must be a distinguished scientist who has made important contributions to exploration geophysics through research. Preference will be given to a scientist whose specialty is seismic properties of earth materials and who has earned the Ph.D. The Schultz Professor will provide leadership and guidance in establishing a quality teaching and research exploration geophysics group. The University of Oklahoma has recently made a strong commitment to the earth sciences with the establishment of a College of Geosciences, to be housed in a new building. The School of Geology and Geophysics will expand from its present faculty of 16 to 26 faculty members by 1986. This will include three scientists in the exploration geophysics area, five in structure-tectonophysics-solid earth geophysics and others in stratigraphy-paleontology, geochemistry-petrology, and energy resources.

Applications are due April 30, 1981. Inquiries, nominations, and applications should be sent to John Wickham, Director, School of Geology and Geophysics, University of Oklahoma, Norman, OK 73019.

The University of Oklahoma is an equal opportunity employer.

Paleontologist. Seek half-time visiting professor for academic year 1981–82 to teach introductory course in paleontology and seminar of own choosing. Appointment is for half-time for entire academic year or full time for fall semester. Ph.D. required. Rank and salary negotiable. Inquiries to: Paul C. Hess, Chairman, Department of Geological Sciences, Brown University, Providence, RI 02912. Deadline for applications is May 31, 1981.

An equal opportunity and affirmative action employer.

Visiting Assistant Professor. One-year, temporary position available August 1981 to teach mineralogy, general geology, and perhaps optical mineralogy. The successful candidate will be required to teach three courses during a two-semester year; someone who enjoys teaching is needed. Persons on leave are encouraged to apply. Deadline for applications is April 17, 1981. Please send resume to David Krinsley, Department of Geology, Arizona State University, Tempe, AZ 85281.

ASU is an equal opportunity employer.

Petrology/Geochemistry, University of New Brunswick. The Department of Geology has a tenure track position available from 1 July, 1981, at assistant professor or higher level. The successful applicant will be expected to teach both undergraduates and graduates as well as carrying out research and supervising graduate students. This position is in addition to one currently advertised for a rock mechanic or geochemist.

The applicant should have a background in petrochemistry and petrology and should be prepared to teach in some aspects of petrology and geochemistry. The successful applicant will be responsible for supervision of analytical facilities including an X.R.F.

Applicants should have a Ph.D. and preferably, post doctoral experience. Applications including a curriculum vitae and names of three referees should be sent to P. F. Williams, Chairman, Department of Geology, University of New Brunswick, Fredericton, N.B. E3B 5A3.

Texas Tech University: Faculty Positions. The Department of Geosciences is seeking applications for additional faculty members in geology, geophysics and geochemistry; applicants from all fields of geology other than paleontology will be given serious consideration.

These are tenure track positions at the assistant professor level with appointments starting September 1, 1981.

Applicants must have completed their doctoral programs, be interested in teaching at both the undergraduate and graduate levels, and have specific plans for research in their fields of specialization.

Applicants for the positions should submit resumes, the names of at least three persons from whom the department may request letters of recommendation, and brief description of research interest to:

Donald R. Haragan, Chairman
Department of Geosciences
Texas Tech University
P.O. Box 4109
Lubbock, Texas 79409

Texas Tech University is an equal opportunity/affirmative action employer.

Faculty Position in Oceanography/Geology: University of Northern Colorado. The Department of Earth Sciences invites applications for a full-time, tenure track faculty position in oceanography, starting September 1981. We are seeking a person with a broad background in oceanography and one or more of the related earth science fields such as marine geology and/or sedimentology. Major responsibility will be teaching beginning and advanced courses in oceanography, courses in the related field, and general education courses. A modest amount of research is possible and is encouraged. Applicants should possess the Ph.D. degree or be in the final stages of completion of that degree. Starting rank and salary will depend on experience and other qualifications of the candidate selected.

Applicants should submit a resume and at least three letters of recommendation to Dr. L. Glen Cobb, Chairman, Department of Earth Sciences, University of Northern Colorado, Greeley, CO 80639.

The deadline for application is May 10.

Hydrogeologist. Applications invited for a permanent faculty position. The position requires a Ph.D., teaching at graduate and undergraduate levels, supervision of research, and research in area of specialty. Interaction with faculty in surface water hydrology, stable-isotope geochemistry, geophysics, and sedimentary geochemistry is expected.

Candidates should send resume, statement of research interest, and addresses of three references to L. D. McGinnis, Chairman, Department of Geology, Northern Illinois University, DeKalb, IL 60115.

An equal opportunity/affirmative action employer.

Atmospheric Scientist/Radiation Physicist. Current Applied Research and Systems activities have created immediate openings in the following areas:

1. Spectroscopy, Radiative Transfer and Atmospheric Sciences (1 Position). Requires to work on the general circulation modeling of stratosphere.
2. Atmospheric Fluid Dynamics (1 Position). Requires to develop global atmospheric dynamics problem in the thermosphere.

These positions are in support of science and application tasks of NASA/Goddard Space Flight Center, Greenbelt, Maryland and require one to work onsite.

An extensive background in the numerical simulation of physical problems by use of mini and large computers is required. Candidates must have M.S. or Ph.D. in atmospheric sciences or physical sciences. Both of these positions are renewable up to two years.

Salary range is $21,000 to $35,000 per annum, depending on qualifications. Good Benefits. Qualified applicants should send three references, salary history and requirements to:

Dr. S. P. S. Anand
Applied Research and Systems
8401 Corporate Drive
Suite 650
Landover, MD 20785
Telephone (301) 459-8442

NORTHWEST PIPELINE CORPORATION

One of our rapidly expanding subsidiary companies, involved in the improvement of pipeline technology, has immediate openings for the following in our Salt Lake City, Utah office:

PROGRAM MANAGER

The candidate we seek will be of either NASA or DOD background, familiar with airborne radar operations and geotechnic studies. Responsibilities will include mission planning, mission operations, system maintenance, and system upgrading of remote sensing platforms. The selected individual will be a Physicist or an Electrical Engineer with a Ph.D., or equivalent. Requires at least five years experience.

STAFF SCIENTIST

The candidate we seek will be of either NASA or DOD background, familiar with imaging radar data produced in the Arctic and other remote sensor data. Responsibilities will include interpretation of data produced by remote sensing platforms. The selected individual will be a Physicist or Geophysical Scientist with a Ph.D., or equivalent. Requires at least three years experience.

If you are interested in this highly progressive company, offering an excellent salary and company benefits, complete with a relocation package, please send your resume in complete confidence to Lynne Petersen, P.O. Box 1526, Salt Lake City, Utah 84110.

An equal opportunity employer m/f.

NORTHWEST PIPELINE CORPORATION

Seismologist: University of Utah. The University of Utah is expanding its geophysics program in the Department of Geology and Geophysics by adding a tenure track faculty member in seismology at the assistant to associate professor level. Applicants with backgrounds and specialities in seismic imaging and theoretical seismology will be given preference. The individual will be expected to teach undergraduate and graduate courses, and to pursue an active research program with graduate students.

The department has modern teaching and research programs in geology and geophysics, and has close associations with the numerical analysis and data processing groups in computer science, electrical engineering, and mathematics. The geophysics component of the department has strong research and teaching programs in electrical and electromagnetic methods, thermal properties of the earth, potential fields, and seismology. Current research in seismology includes: earthquake research utilizing a new PDP 11/70 computer; monitoring of the Intermountain seismic belt by a 55 station telemetered network utilizing a new on-line PDP 11/34 computer; major experiments in seismic refraction and reflection profiling for crustal structure, and allied research in tectonophysics of mountain building.

The closing date for applications is May 1, 1981 and the appointment date is September 1981. However, the search may be extended if a suitable candidate is not selected, in which case applicants for a one-year visiting position for the academic year 1981–82 will also be considered.

A Ph.D. is required for this position.

Applicants should submit a vita, transcripts, a letter describing his/her research and teaching goals, and names of five persons for reference. Qualified persons should send their applications to William P. Nash, Chairman, Department of Geology and Geophysics, University of Utah, Salt Lake City, Utah 84112.

University of Utah is an equal opportunity/affirmative action employer.

Purdue University. A tenure track appointment in the area of surveying and mapping. Undergraduate teaching in the areas of basic surveying, adjustment computations, and introductory photogrammetry/photo interpretation; involvement in teaching graduate level courses, and in existing and new research programs.

Preferential consideration to candidates with a Ph.D, and land surveying registration (or in the process of getting such degree and registration); rank and salary are open and depend on the experience and qualifications of the applicant.

Send resumes, by 15 April 1981, to Head, School of Civil Engineering, Purdue University, West Lafayette, IN 47907.

Purdue is an equal opportunity/affirmative action employer.

Head: Earth Resources Branch, NASA/Goddard Space Flight Center. GS-1330-14/15: $37,871-$50,112 per annum, full-time permanent. The Earth Survey Applications Division, Applications Directorate, NASA/Goddard Space Flight Center invites applications for the open position of Head, Earth Resources Branch. The incumbent of this position is responsible for planning, managing, and conducting broad programs in earth resources remote sensing basic and applied research and data analysis, emphasizing the development and demonstration of applications of remote sensing of earth resources from earth orbiting satellites. The primary areas of research in the Branch are land use management, vegetation sciences including agriculture/forestry/rangeland and environmental monitoring utilizing remotely sensed data and advanced technologies. Also, significant effort is dedicated to sensor data evaluation in terms of applications and scientific utility, and to specification of data acquisition and information extraction systems which best meet user scientific and resource management needs. An advanced degree in earth or physical sciences is required with education in the vegetation sciences, land use or environmental monitoring being specifically preferred. Candidates should also have several years of progressively more responsible experience in the conduct, guidance and management of remote sensing research programs and clear evidence of a strong research background indicating senior research scientist stature.

Resumes/SF 171's should be sent to:
Dr. Robert D. Price, Assistant Chief
Earth Survey Applications Division
Code 920
Goddard Space Flight Center
Greenbelt, MD 20771

Deadline for applications is April 30, 1981.

University of Hawaii. The Hawaii Institute of Geophysics and the Department of Geology and Geophysics of the University of Hawaii invite application for tenure track positions available July 1, 1981. Applicants with specialties in any of the following fields will be given consideration:

1. Marine geophysics with emphasis in marine gravity and tectonics
2. Marine seismology
3. Marine magnetics

Applicants should have a Ph.D. degree and a demonstrated ability to conduct and promote marine research. Ability to teach at all levels is required. The position will be a joint one on an 11-month basis between the Hawaii Institute of Geophysics and the Department of Geology and Geophysics. The appointments will be at the rank of assistant professor.

Apply with resume and names of three references to Charles E. Helsley, Director, Hawaii Institute of Geophysics, University of Hawaii, Honolulu, Hawaii 96822. Closing date is May 15, 1981.

The University of Hawaii is an affirmative action and equal opportunity employer.

Chemical Oceanography/Marine Geochemistry. Anticipated faculty opening at Florida State University. Applicants from all specialties welcome—preference to candidates who enhance existing programs in marine and atmospheric chemistry sedimentary geochemistry and radiochemistry. Contact, Chairman/Chemical Oceanography Search Committee, Department of Oceanography, The Florida State University, Tallahassee, FL 32306. Telephone 904/644-6700.

Meteorology Studies Program Coordinator. The University of North Dakota anticipates offering an undergraduate degree in Meteorological Studies beginning the fall semester 1981. This program will be very applications oriented, and will include courses in dynamics, synoptics, radar meteorology, cloud physics meteorology, and forecasting among others. This co-sponsored program requires 40 hours for a major, plus twelve hours of calculus and twelve hours of physics, and will utilize to a great degree the research staff and facilities in the co-sponsoring departments of aviation and geography.

The coordinator's position will include general overall administrative responsibility for the program on a day to day basis, teaching of courses in synoptics, dynamics, and radar meteorology as well as being the primary student advisor for the program. Additionally, the position offers an excellent opportunity to be involved in research associated with the department of aviation's multi-year, multi-million dollar research contracts. Facilities include a Citation II jet cloud physics aircraft, a Cheyenne turboprop research aircraft, a Blanik glider, a 5 cm digital weather radar, and a dedicated computer facility.

The position is a 12 month non-tenured appointment within the department of aviation beginning 1 July 1981. The position requires a Ph.D. in meteorology and a strong background in teaching. A specialization in radar meteorology is preferred. Salary is commensurate with experience ($25,000–$35,000).

The Department has experienced phenomenal growth in academics and research these past years, and encourages applicants to send their resumes by 1 June 1981 to: Dr. Patrick J. Brady, Department of Aviation, Box 8216—University Station, Grand Forks, ND 58202. The University of North Dakota offers an attractive benefits package, retirement plan, and excellent working conditions.

UND is an equal opportunity employer.

MARINE RESEARCH ASSOCIATE II.

Analyze and interpret vertical acoustic travel time and pressure data. Prepare progress and data reports. Assist in planning experiments, instrument design modifications, instrument preparation, and at-sea deployment and recovery operations. Develop empirical and dynamical models to be evaluated using EPOCS data. Ph.D. in physical oceanography plus experience in computer programming (applications) and FORTRAN. Submit resume by May 31, 1981 to Dr. Mark Wimbush, Watkins Building, Bay Campus.

UNIVERSITY OF RHODE ISLAND
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Postdoctoral/Research Associate Positions, The Johns Hopkins University, Applied Physics Laboratory. Positions are available for studies of magnetospheric-ionospheric coupling, hydromagnetic waves, and plasma instabilities in the ionosphere and magnetosphere. The selected candidates will participate in the analysis and interpretation of data from spacecraft and ground-based radars as well as in the development and implementation of new ground-based and spacecraft studies. Positions are for one year and are renewable. Tenure may begin at any time through September 1, 1981. Applications should be addressed to Mr. Steven F. Sayre, Dept. ADI-15, The Johns Hopkins University, Applied Physics Laboratory, Johns Hopkins Road, Laurel, MD 20820.

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MARINE RESEARCH SPECIALIST II.

Perform chemical research on organic pollutants in marine samples. Collection, preparation, and chemical analysis of samples. Candidate must have B.S. or M.S. degree and be familiar with gas chromatographic methods for the analysis of synthetic organic compounds in samples of water, sediment, and organisms. Knowledge of field sampling techniques would be helpful. Submit resume by April 30, 1981 to Dr. James G. Quinn, Graduate School of Oceanography.

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Meetings

Pacific Energy and Minerals

A call for papers has been issued for the Third Circum-Pacific Energy and Mineral Resources Conference, scheduled for August 22–28, 1982, in Honolulu, Hawaii. Theme of the conference is 'Resources for the '80's.'

In addition to the regular conference sessions, preconference workshops will be held on August 21–22. A preconference symposium on August 20 on Energy Research in the Circum-Pacific Region will be sponsored by the International Union of Geological Sciences. Geological field trips and tours to other Hawaiian Islands are slated for the week after the conference.

Abstracts for oral and poster papers should be received by January 1, 1982. Names of the appropriate program chairmen who should receive abstracts can be obtained by writing to Allen Mabra, Vice President for Exploration, ARCO International Oil and Gas Co., 515 South Flower Street, AP-4985, Los Angeles, Ca 90071.

To receive complete conference details, reservation forms, and travel information, contact the AAPG Convention Department, P.O. Box 979, Tulsa, OK 74101 (telephone 918/584-2555).

International Groundwater

A symposium entitled 'International Groundwater—The Promise and the Problems,' is scheduled for May 13 and 14 in New York City. Organized by the American Society of Civil Engineers' Groundwater Committee (part of the Irrigation and Drainage Division), the sessions form part of the society's International Convention and Exposition on May 11–15 at the New York Hilton Hotel.

The program will consist of 12 papers and two panel discussions. International groundwater occurrence, development, and problems will be discussed by specialists from the United Nations and Food and Agriculture Organization, as well as from Australia, Egypt, Finland, India, Israel, Pakistan, Saudi Arabia, Thailand, the United States, and West Africa.

For more information, contact A. Ivan Johnson, Woodward-Clyde Consultants, 209 West 7th Avenue, Denver, CO 80204 (telephone: 303/573-7882).

AGU Midwest Meeting

September 17–18
Minneapolis, Minnesota

Abstract Deadine: July 1
Convenor: V. Rama Murthy

Papers and posters originating in or pertaining to the region are solicited for the following special sessions:

Mantle structure and dynamics. Contact Geoffrey Davies or Clem Chase.

Rock water interactions: Hydrothermal processes and metallogenesis. Contact William Seyfried.

Precambrian crustal evolution of the North American continent. Contact Paul Weiblen.

Geomagnetism and paleomagnetism. Contact Subir Banerjee.

Hydrology in the mid-continental U.S. Contact H. O. Pfannkuch or E. C. Alexander, Jr.

Abstracts

Use standard AGU format (see page 20 of January 13 *Eos*) and send original and two copies of abstracts to AGU Midwest Meeting, 2000 Florida Avenue, N.W., Washington, D.C. 20009. Abstracts will be published in *Eos*, with a substantive meeting report after the meeting. There will be no abstract charge.

AGU Job Center at Spring Meeting

AGU will initiate a Job Center for the benefit of registrants and prospective employers at the Spring Meeting in Baltimore. The purpose of this center is to facilitate scheduling of interviews between registrants seeking employment and employers seeking qualified personnel to fill their job vacancies. Job descriptions of open positions will be posted on bulletin boards at the center. Employers planning to attend the meeting should bring job descriptions for posting to the registration desk and fill out a form indicating when someone will be available for interviewing.

Job candidates should bring resumes with them to the meeting. Resumes will be held confidentially but will be open for review by registered prospective employers. Job candidates can review the posted positions and sign up at the Job Center desk.

Interviewing will take place from 9 am to 4 pm Tuesday through Thursday in Exhibit Hall A. Applications and job descriptions can be left at the Job Center in the Baltimore Convention Center from 8 to 4 from Monday on.

Penrose Conference on Antarctica

A Penrose Conference scheduled for April 11–16, 1982, will focus on the global significance of the Antarctic plate. Sponsored by the Geological Society of America, the conference will be held in Shenandoah National Park, Virginia.

Antarctica is central to several problems of global geologic significance, including the processes of continental fragmentation, as exemplified by Gondwanaland breakup; the nature and development of the present Antarctic plate; the plate's configuration and interaction with adjacent plates during the late Mesozoic and Cenozoic; and the development of Southern Ocean circulation and paleoclimatic change. The purpose of the conference is to bring together scientists from many disciplines to address these problems.

Registration fee for the conference: approximately $350 per person. Special travel arrangements will be made from Washington, D.C. Attendance at the conference is limited to 70.

For an application or additional information, contact either of the convenors: Ian W. D. Dalzell, Lamont-Doherty Geological Observatory, Columbia University, Palisades, NY 10964, or David H. Elliot, Institute of Polar Studies, The Ohio State University, Columbus, OH 43210. Application deadline is November 1.

Rock Mechanics Symposium

The Massachusetts Institute of Technology will sponsor the 22nd United States Symposium on Rock Mechanics, June 29–July 2. Designed for geophysicists, civil and petroleum engineers, and rock physicists, the conference will include papers and discussions on energy, mineral extraction, civil construction, and waste disposal.

Among the topics to be discussed are heat and fluid flow, fragmentation and fracture propagation, deformation of rock masses, and site characterization.

Field trips will be conducted through Boston's Red Line subway extension tunnel as well as through the Seabrook Nuclear Power Station cooling water tunnel.

For additional information, contact the seminar office at 617/253-7461, or write to Barbara Dullea, Coordinator, Center for Advanced Engineering Study Seminars, MIT, Cambridge, MA 02139.

Sail into Baltimore

AGU Spring Meeting

May 25–29

Session Highlights

Solar-Planetary Relationships

SPR—Cosmic Rays and SPR—Solar and Interplanetary Physics

A Celebration of the 25th AU Crossing of Pioneer 10

Pioneer 10 was launched in 1972 to perform the first flyby of Jupiter and the first exploration of the distant heliosphere. In celebration of Pioneer 10's 25th AU crossing, the principal investigators on the heliospheric investigations—J. Van Allen, F. McDonald, J. Simpson, E. Smith, and A. Barnes—will review their latest results in a special symposium to be held on Tuesday Afternoon in room 310.

Solar Flare Particle Composition

One of the intriguing results in recent years is the anomalies and the systematic variations observed in the composition of energetic particles in solar flare events. In a special session on Wednesday morning, E. Stone and G. Mason will review recent observations and theories for the composition in flare events, and a variety of contributed papers will be given on current work in this field.

Solar Flare Particle Acceleration

A problem of longstanding and current interest is the mechanism responsible for particle acceleration in solar flare events. In a special session scheduled for Wednesday morning, P. Sturrock will review the current status of theories of particle acceleration in flares, and K. Frost will summarize the results from the Solar Maximum Mission. A variety of contributed talks will be given on recent experimental and theoretical results.

Waves and Turbulence in the Solar Wind

The solar wind is an ideal laboratory in which to test our understanding of the properties of waves and turbulence in a large-scale astrophysical plasma. In a special session scheduled for Thursday afternoon, C. Sonett will review recent observations of waves and turbulence in the solar wind, and A. Barnes will review the current theoretical understanding. A variety of contributed talks will be given on recent experimental and theoretical results.

SPR—Aeronomy

Spectroscopy in Geophysics On the Centenary of Rowland's Ruling Engine at the Johns Hopkins University

Baltimore is the home of the Johns Hopkins University, famous for its School of Medicine, but also known for its alumni who have made significant contributions to modern-day geophysics. These include, for example, Edwin O. Hall (discoverer of the 'Hall' effect while pursuing his Ph.D. back in 1879) and Henry Rowland (inventor of the ruling engine a century ago). Rowland's engine allowed grating spectroscopy to be developed into a technique now used in a variety of disciplines ranging from the earth's atmosphere to astrophysics. A special session commemorating the centenary of Rowland's invention is scheduled for Monday. Following an introduction by W. G. Fastie (inventor of the Fastie-Ebert spectrometer) on the legacy of Rowland, a series of invited and contributed papers will review the contributions in grating spectroscopy in aurora, the atmosphere, the magnetosphere, the sun, planets, and comets.

Atmospheric Chemistry

A series of four sessions on atmospheric chemistry (sponsored by SA and M) is scheduled for Tuesday and Wednesday, May 26 and 27. The topics will range from the earth's surface, through the stratosphere, and up to the mesosphere and D region ionosphere. The session on Wednesday morning will focus completely on the subject of ozone, perhaps the most critical ingredient in the earth's atmosphere. A series of 14 contributed papers will describe rocket, balloon, and satellite observations of ozone, and theoretical and model studies involving ozone. Ozone is a principal factor in the earth's climate and plays an important part in human-society-produced pollution effects (namely as a barrier against some cancer-producing solar rays).

The Chatanika Radar

The powerful radar system located at Chatanika, Alaska, for the past decade has provided detailed measurements of densities, electric currents, and fields in the high latitude, ionosphere, and atmosphere. These unique observations made on the earth's surface have been used in a wide range of correlative satellite, rocket, and surface experiments. They have made possible significant contributions to an understanding of auroral and magnetospheric processes. A special session will review the past contribution of the Chatanika radar and describe the planned move of this major facility to Greenland. The session is scheduled for all day May 28, and will include invited papers by R. R. Vondrak and J. D. Kelly of SRI and P. M. Banks of the University of Utah. T. Stockflet Jørgensen of the Danish Meteorological Institute will review plans made for the Chatanika radar's future after it moves to Greenland.

SPR—Magnetospheric Physics

The magnetospheric section (SM) will be sponsoring four special sessions. Two will consist of invited papers for oral presentation. The other two special sessions will consist of contributed poster papers. The special poster sessions will be held Monday afternoon, but facilities will be available for authors to exhibit their posters all day. The scheduled poster papers include 11 in a special session on Waves, Instabilities, and Turbulence in Space Plasmas and 10 in a special session, organized by Joe Barfield, on Birkeland Currents. The use of posters on such a large scale in regular meeting rooms will be a new experience for many AGU participants. This method of presentation has been well received in other professional societies, and we hope that it will be equally successful in the AGU. Seven more poster papers will be presented in a 'potpourri' session Thursday afternoon, following the SPR luncheon.

On Wednesday morning there will be a special session of invited talks on the Auroral Potential Structure. The program of speakers for this session includes Dave Evans, Joe Fennell, Forrest Mozer, Larry Lyons, Y. T. Chiu, H. L. Rowland, and Bob Hoffman. The special session for Friday afternoon will feature five invited talks and a period of open discussion on the extraction of Solar-Planetary Data from History and Folklore. This is a novel topic for the AGU, and those who attend will be well rewarded by the broadening of their horizons. Speakers will include Bob Eather, George Siscoe, Asgeir Brekke (or Alv Egeland), Joan Feynman, and Sam Silverman. The Friday program also features 29 contributed magnetospheric papers on Jupiter, Saturn, and their satellites.

Planetology

Upper and Lower Atmosphere of Venus

A full day on Friday will be devoted to a discussion of the Venusian atmosphere. Presentations will focus on the structure and dynamic processes within the thermosphere, ionosphere, and lower atmosphere of the earth's sister planet. These presentations will be based to a large extent on extended analysis of data obtained by the Pioneer Venus spacecraft. Specific topics to be addressed include variations between the daytime and nighttime atmosphere, coupling of the upper atmosphere with the solar wind, spatial and temporal variability in the position of the ionopause, and the distribution of sulfur dioxide in the lower atmosphere. This session also contains a special report on the recent discovery of natural gain amplification within the infrared spectra of the Martian atmosphere.

Geologic Processes on Icy Bodies

This special session is devoted to the icy moons of Jupiter—Ganymede, Europa, and Callisto. Presentations will focus upon the distinctive surface morphology of the bodies and various models that are being proposed to account for these features. Unique types of 'thin-skin' tectonic deformation and phreatic volcanic activity may occur on these icy bodies, where water ice is inferred to be a major constituent of the planet's crust. Cratering mechanisms on Jupiter's moons should also differ significantly from those that have operated on the terrestrial planets. This special session, scheduled for Thursday afternoon, emphasizes the challenge of comparative planetary studies in treating geologic phenomena that are clearly beyond our terrestrial experience.

Meteorology Oceanography Geodesy

SEASAT

Five sessions (Monday, Tuesday, and Wednesday) will be held for presentation of initial results obtained from the SEASAT satellite. Three sessions will be sponsored by oceanography, one each by meteorology and geodesy. These sessions will cover analyses of data from the microwave radiometer, radar altimeter, scatterometer, and synthetic aperture radar.

Hydrology

Acid Rain

Acid rain has received considerable attention in recent years because of its effects on the environment. This session, scheduled for Monday afternoon, will cover topics ranging from the effects of acid rain on aquatic ecosystems to the acid loadings from snowmelt. Recent development of long-range transport models will also be addressed.

Symposium on the National Urban Runoff Programs

A full-day program (May 26) on the National Urban Runoff Program (NURP) will be followed the next morning by a field trip to the urban runoff monitoring sites in Baltimore. The symposium will include an overall view of EPA's objectives for NURP, case histories, USGS studies, and designs of monitoring systems.

Water: A Constraint on Synthetic Fuel Development

There will be brief presentations by speakers from the government, consulting firms, universities, and industry, who will also participate in a panel discussion. Topics will include the national, regional, and industrial perspectives, the water requirements for synfuel plants, available data, and a case study. This symposium, scheduled for Tuesday afternoon, will begin with two papers on the effect water availability has on the development of synthetic fuels.

John Ferris Symposium on Groundwater Hydraulics

For more than three decades, as both a nationally and internationally renowned researcher and teacher, John Ferris has contributed to basic scientific knowledge and general application of principles of hydraulics to the solution of groundwater problems. During this period, the methodologies for application of hydraulics to solving groundwater problems have continued to evolve and improve. The development of aquifer test techniques and analytical solutions commonplace in the 1950's, '60's, and early '70's are now increasingly supplemented by the use of numerical models and automated parameter estimation techniques.

The purpose of this all day symposium on May 27 is to explore the broad application of hydraulics to the solution of groundwater problems through review of methods used in the last three decades and through presentation of the latest research and sophisticated state-of-the-art techniques.

What Geochemistry Can Tell Us About Background Water Quality

Geochemistry can be used as a tool to interpret water quality. On Thursday afternoon this symposium will explore controls on the phosphorus cycle, the prediction of calcium and magnesium concentrations in arid soil waters, chemical reactions in groundwater, and controls on isotopic compositions of groundwater systems.

Trace Organics in Groundwater

More and more trace organics are being found in groundwater. These organics often pose problems to the public health. On Thursday morning this symposium will explore some of these present problems and describe the history of organics in the groundwater of specific areas.

Relating Drinking Water and Health: The Need for Data Banks

This special session focuses on the need for data banks to determine possible relationships existing between drinking water and health. Existing data banks and storage and retrieval systems are presented, and the need for further data collection and analysis systems will be discussed.

GAP

Geotectonics

Volume 14, Number 2, 1980

CONTENTS

Chronicles

Aeronomy

0430 Composition (atomic or molecular)
A METEOR-ABLATION MODEL OF THE SODIUM AND POTASSIUM LAYERS
D.M. Hunten (Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona 85721)

Recent results on meteor ablation are used as input to a model in which ablation (or evaporation) is the source and deposition on dust particles is the sink. The dust comes from recondensation of the rest of the meteor vapor. An excellent match is found to the observed characteristics of the sodium layer. It is argued that the high-latitude winter maximum of abundance (and layer height) is due to the much lower rate of ionization there and over the polar cap. The computations show the required factor of 4-5 and also match the height variation. To keep the ion density from being too large, downward electrodynamic transport at ~50 cm/sec must be invoked. The different behavior and low abundance of potassium require an additional sink. The one proposed is Penning ionization by metastable excited O_2. Inherent in the model is that sodium and its compounds reside almost entirely on dust particles below 80 km. Large abundances in the free form at stratospheric heights are very unlikely and are not a good explanation of observed ambient ions. (Ionosphere, Sodium, aeronomy, meteors).
Geophys. Res. Lett., Paper 1L0442

0430 Composition (atomic or molecular)
THE GLOBAL DISTRIBUTION OF NITRIC OXIDE AT 200 KM
T. E. Cravens (Space Physics Research Laboratory, Department of Atmospheric and Oceanic Science, The University of Michigan, Ann Arbor, Michigan 48109)

Measurements of nitric oxide at 200 km by the ultraviolet nitric oxide experiment on Atmosphere Explorer D are used to demonstrate the dependence on NO on latitude, longitude, and magnetic activity. NO is more abundant in the summer hemisphere than in the winter hemisphere and is more abundant during magnetically active times than during quiet times. A simple photochemical theory is used to show that the knowledge of local composition and temperature is sufficient to explain the variations of nitric oxide at this altitude.
J Geophys. Res., Blue, Paper 1A0246

0430 Composition
IN SITU OBSERVATIONS OF ClO IN THE STRATOSPHERE: A REVIEW OF RECENT RESULTS
E.M. Weinstock (Center for Earth and Planetary Physics, Harvard University, Cambridge, MA 02138) R.J. Phillips and J.G. Anderson

A summary of the results of ten balloon-borne in situ measurements of ClO in the stratosphere is presented. All observations were carried out close to local noon at 32°N latitude with solar zenith angles between 24° and 55°. The mean of nine of the observations, which for the most part fall within a well defined envelope, is compared with a recently calculated [ClO] distribution between 25 and 42 km at the appropriate latitude and time of day. It is found that, while reasonable agreement exists in the 35-40 km region, the ratio of calculated to observed [ClO] increases monotonically with decreasing altitude below 35 km, reaching approximately three at 25 km. The tenth observation exhibits a mixing ratio nearly an order of magnitude greater than the mean. An analysis of the relevant chemistry below 30 km is presented which indicates that the discrepancy between the observed mean and the calculated [ClO] distribution can be linked to uncertainties in the [OH]/[NO] ratio in the lower stratosphere. A comparison is made between the in situ resonance fluorescence observation reported here and the remote laser heterodyne radiometer measurements of Menzies. Finally, the fractional destruction of $O_x = O_3 + O(^3P)$ by $ClO_x = Cl + ClO$, based on the in situ ClO and $O(^3P)$ midday observations, is presented for the altitude interval 27-41 km.
J. Geophys. Res., Green, Paper 1C0276

0770 Radio Oceanography
SEA-STATE FREQUENCY FEATURES OBSERVED BY GROUND-WAVE HF DOPPLER RADAR
P. Forget (LSEET, Université de Toulon, 83130 La Garde, France) P. Broche, J.C. de Maistre and A. Fontanel

This paper investigates the relationship between the frequency features of the directional spectrum of ocean waves (cutoff frequency and peak frequency of wind waves, frequency of quasi monochromatic swell) and the properties of the spectrum of the sea echo obtained by HF Doppler radar.

A theoretical analysis is performed to check the validity of a simple result that states that at upper HF, a long-wave spectral feature at frequency F_0 affects the radar echo at frequencies $\pm f_B \pm F_0$ on either side of the Bragg lines at $\pm f_B$ corresponding to resonant backscattering of radio waves with a given wavelength by half-wavelength ocean waves.

An experiment using both radar and standard in-situ measurements for several weeks at different times of the year shows that this relationship can be used to formulate a method for estimating the frequency features of the sea with suitable accuracy.
Rad. Sci., Paper 1S0450

0770 Radio oceanography
OCEAN SURFACE HEIGHT-SLOPE PROBABILITY DENSITY FUNCTION FROM SEASAT ALTIMETER ECHO
E. Lipa (SRI International, Remote Measurements Laboratory) D. Barrick

This paper describes new methods for the interpretation of microwave scatter from the sea. Rough-surface scattering theory has led to an integral equation for the echo voltage in terms of the joint height-slope probability density function (pdf). We have developed methods for the inversion of this equation that do not require the assumption of a model for either the ocean surface or the transmitted pulse. In addition they are far more efficient than traditional grid-search methods for model fitting.

We have applied our methods to SEASAT data taken over Hurricane Fico. Statistical data analysis was performed to give the data covariance matrix and the correlation coefficient between successive waveforms and to trace the propagation of error through the inversion process to give statistical uncertainties in the derived parameters. The usual assumption of Rayleigh statistics is shown to be violated by the data, since the number of degrees of freedom increases linearly with power, independent of sea-state; we conclude that this is an instrumental effect. We find that the waveforms are significantly correlated over distances of several kilometers at high sea-states, and suggest coherence of long ocean waves over these distances as the cause.

We obtained waveheight higher-order parameters by least-squares fitting of a Gram-Charlier model for probability densities to the calculated values. For averages over 160 km of sea, we obtain a mean surface height bias correction, significant waveheight and height skewness parameter with standard deviation of 4%, 0.7% and 10%. In addition to this height bias correction easily removed from the data, we identify another sea-state-dependent height bias that can exceed 50 cm. That this exists in the data is proof that one must employ the joint height-slope pdf in the scattering model, and not merely the height pdf as conventionally used. (Radar altimetry, ocean waveheight, sea surface topography)
J. Geophys. Res., Green, Paper 1C0428

0780 Scattering
CHEMICAL FLUCTUATIONS AND INCOHERENT SCATTERING THEORY IN THE TERRESTRIAL D-REGION
G. Kockarts (Institut d'Aéronomie Spatiale B-1180 Bruxelles, Belgique) G. Wisemberg

The continuum theory of incoherently scattered electromagnetic waves is modified in order to include possible effects of thermally induced chemical fluctuations. These fluctuations are taken into account by introducing fluctuating parts in the production and loss terms of the continuity equations. An equivalent ionospheric model is developed for three types of ionized species, i.e. electrons, negative and positive ions. A matrix formulation gives simultaneous access to fluctuating parts of each charged component. Numerical results indicate that chemical fluctuations are important over the height range where negative ions are comparable or greater than the electron concentration. Strong enhancements of the incoherent scatter cross section occur for frequency shifts smaller than approximately 20 Hz. A simple approximation is given for the contribution of chemical fluctuations.
(D Region, negative ions, incoherent scattering).
J. Geophys. Res., Blue, Paper 1A0481

0780 Scattering
SCATTERING CROSS SECTIONS FOR COMPOSITE RANDOM SURFACES—FULL WAVE ANALYSIS
Ezekiel Bahar (Electrical Engineering Department, University of Nebraska-Lincoln, Lincoln, Nebraska 68588)

The full wave approach to rough surface scattering is applied to composite models of rough surfaces. In this work the principal distinguishing features of the individual rough surface is its correlation distance. Thus this model can be applied to scattering by rough seas as well as hilly terrain. It is shown that the full wave approach accounts for both specular scatter and Bragg scattering. The scattering cross section for the composite surface, with two or more roughness scales, is shown to be a weighted sum of the scattering cross sections for the individual rough surface heights. Shadowing effects are accounted for explicitly in the analysis. The full wave solutions satisfy reciprocity, duality and realizability relationships in electromagnetic theory.
Rad. Sci., Paper 1S0478

Electromagnetics

0703 Antennas
POLARIZATION ERRORS IN A TWO-CHANNEL SYSTEM
G.C. McCormick (RB2, Granville Ferry, Nova Scotia, B0S 1K0, Canada)

The two-channel system includes a two-terminal antenna with ancillary devices. A general treatment of polarization errors in such a system is given, including the transformation of error parameters and scattering coefficients with a change of polarization base. Calibration procedures are discussed and formulas developed for the calculation of polarization-related quantities in the presence of errors.
Rad. Sci., Paper 8S1055

0703 Antennas
NETWORK LOADING OF THIN-WIRE ANTENNAS AND SCATTERERS IN THE TIME DOMAIN
J. A. Landt
Los Alamos National Laboratory, Los Alamos, NM 87545

A numerical technique is presented that is capable of calculating the transient response of a thin-wire antenna or scatterer loaded by a network. The electromagnetic formulation is an adaptation of a well validated and widely used code. This code is based on an electric field integral equation and employs point matching and 9-point Lagrangian interpolation functions. The network is treated by a nodal analysis and can contain a finite number of lumped and possibly nonlinear elements. The formulation is cast in the time domain, and the solution is obtained by a time-stepping procedure. The numerical approach is outlined and the responses of several examples are presented. (Numerical methods, transients, loaded antennas, wire antennas.)
Rad. Sci., Paper 1S0500

Exploration Geophysics

0920 Magnetic and electrical methods
RESTRICTIONS ON THE USE OF COLE-COLE DISPERSION MODELS IN COMPLEX RESISTIVITY INTERPRETATION
J. Major (Bureau of Mineral Resources, P. O. Box 378, Canberra City, A.C.T. 2601, Australia) J. Silic

The Cole-Cole dispersion approximates the behavior of inductive coupling over only a part of the frequency range. We show that the interaction between the induced polarization (IP) and inductive coupling (IC) effects will, in general, be more complicated than a multiplication of two Cole-Cole dispersions representing the separate IP and IC effects. The inversion of published data shows that the time constant (τ_1) of the IP effect is often a poorly defined parameter. Hence, small changes in the parameters used to approximate inductive coupling by a Cole-Cole dispersion can produce very large changes in the calculated value of τ_1. From these considerations, guidelines are developed to show when the Cole-Cole dispersion may be successfully used to approximate inductive coupling and define τ_1.
Geophysics, Vol. 46, No. 6

0920 Magnetic and electrical methods
THE ELECTROMAGNETIC FIELD OF A HORIZONTAL DIPOLE OVER A VERTICALLY INHOMOGENEOUS AND ANISOTROPIC EARTH
M. Chlamtac (Department of Mathematical Sciences, Tel Aviv University, Ramat-Aviv, Tel Aviv, Israel) F. Abramovici

Electromagnetic (EM) field components are expressed as a set of improper integrals, the integrands of which depend upon two impedance functions that satisfy nonlinear differential equations. The components are normalized with factors representing the solution for a homogeneous half-space having the same conductivity characteristics as the first layer. The normalized components of the magnetic field depend only upon the longitudinal conductivity σ_l. Their variation with normalized distance d_1 (actual distance divided by first-layer skin depth computed using σ_1) reflects the change of resistivity with depth. The normalized components of the electrical field depend upon both σ_l and transversal conductivity σ_t and thus reflect changes with depth of both $1/\sigma_l$ and $1/\sigma_t$. The examples considered show that anisotropy is felt for small normalized distances. Transition layers result in moderate variation of the field components with d_1 as compared to stacks of homogeneous layers presenting abrupt changes in electrical properties of the structure.
Geophysics, Vol. 46, No. 6

0930 Seismic methods
ANALYSIS OF DISPERSIVE WAVES BY WAVE FIELD TRANSFORMATION
See 0910 Computer applications
George A. McMechan (Formerly Stanford Exploration Project, Department of Geophysics, Stanford University, Stanford, CA 94305; presently Pacific Geoscience Centre, Earth Physics Branch, Department of Energy, Mines, and Resources, Box 6000, Sidney,

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0930 Seismic methods
DIRECT RECONSTRUCTION OF VELOCITY AND DENSITY PROFILES FROM SCATTERED FIELD DATA
See 0910 Computer applications
S. Raz (The Technion-Israel Institute of Technology, Department of Electrical Engineering, Technion City, Haifa 32 000, Israel)

A direct Born inversion algorithm is presented which separates the effects of stratified medium velocity and density gradients, thus facilitating the simultaneous reconstruction of the velocity and density profiles from scattered field data.

A significant but not unexpected conclusion is that velocity and density variations cannot be separated and resolved from data acquired by a single source-receiver configuration. Measurements at a minimum of two offset angles are required.
Geophysics, Vol. 46, No. 6

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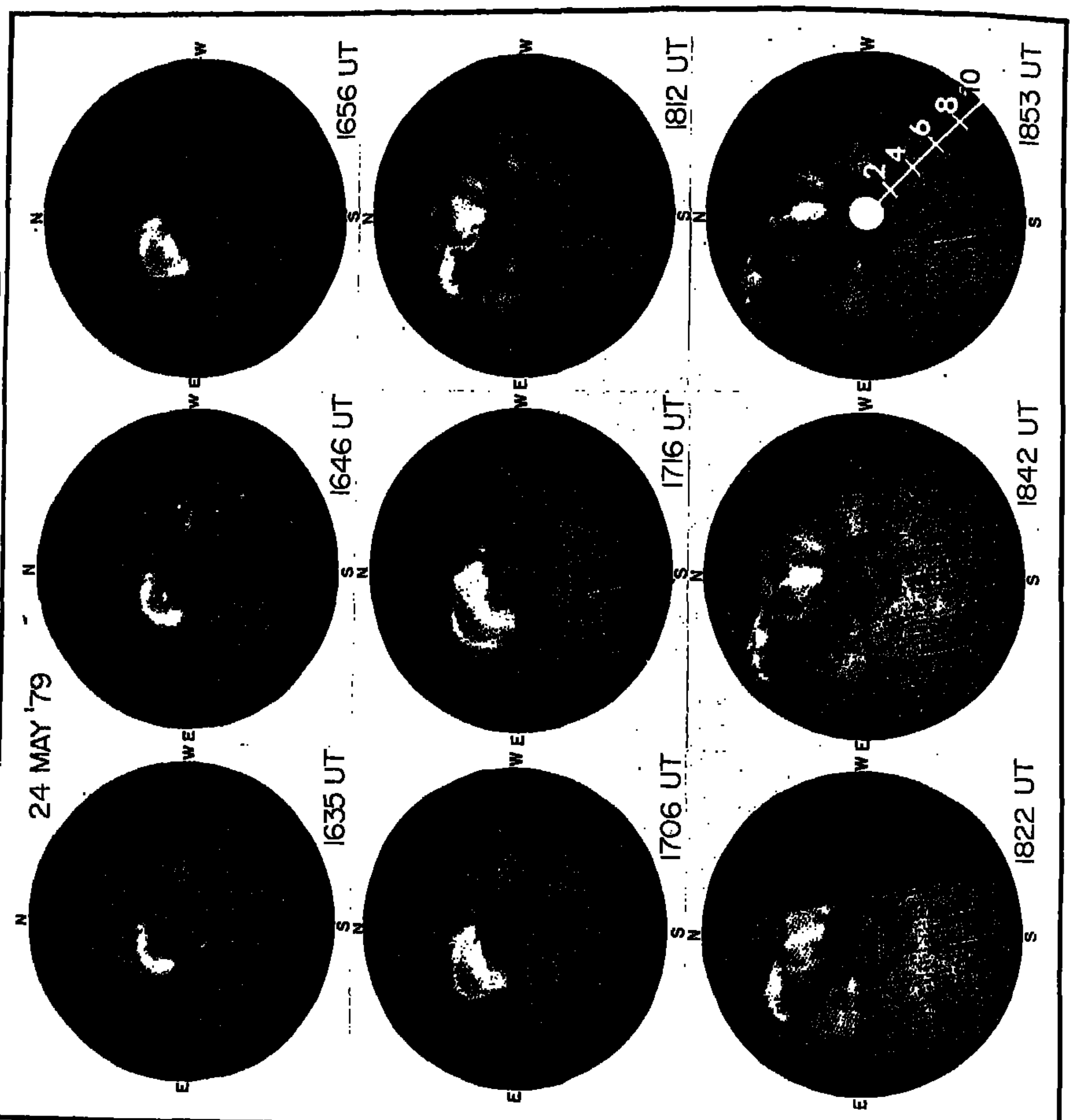

EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION VOL. 62, NO. 15, PAGES 153-161 APRIL 14, 1981

Geochemistry

1410 Chemistry of the atmosphere
MEASUREMENTS OF CF_2Cl_2, $CFCl_3$, AND N_2O IN THE LOWER STRATOSPHERE BETWEEN 2° S AND 73° N LATITUDE
J. F. Vedder (NASA Ames Research Center, Moffett Field, CA 94035) E. C. Y. Inn, B. J. Tyson, C. A. Boitnott, and D. O'Hara

Mixing ratios are presented for CF_2Cl_2, $CFCl_3$, and N_2O in the lower stratosphere. They are derived from measurements made on samples collected by a high-altitude aircraft during a survey in the Northern Hemisphere in the summer of 1977. The vertical distributions of the mixing ratios of these species show a decrease with increasing altitude and a marked decrease at a given altitude with increasing latitude from 2° S to 73° N latitude. These results agree with our measurements at similar latitudes in the fall of 1976 and with results of other experiments. The experimental apparatus and procedures are described in greater detail than in previous papers. (Mixing ratios, stratosphere, latitude, apparatus).
J. Geophys. Res., Green, Paper 1C0392

1410 Chemistry of the atmosphere
SIMULTANEOUS MEASUREMENTS OF NO_x, NO, AND O_3 PRODUCTION IN A LABORATORY DISCHARGE: ATMOSPHERIC IMPLICATIONS
Joel S. Levine (NASA Langley Research Center, Hampton, Virginia 23665), Robert S. Rogowski, Gerald L. Gregory, William E. Howell and Jack Fishman

Simultaneous measurements of NO_x ($NO + NO_2$), NO, and O_3 production in a laboratory discharge show that within the uncertainties of the experiment, all of the NO_x produced was NO, and no detectable enhancement of O_3 after the discharge was observed. The laboratory experiments described give an NO production rate of $5 \pm 2 \times 10^{16}$ molecules joule^{-1} for a 10^5 – 10^6 joules m^{-1} spark. Assuming that the global dissipation of lightning energy is about 10^{-8} joules cm^{-2} s^{-1} (Devan, 1980; and Hill et al., 1980), our NO production rate results in a global source of NO due to lightning of about 1.8 Mt(N)/yr, which is considerably lower than earlier estimates. This lower value for NO_x production by lightning suggests that NO_x emissions from anthropogenic sources, estimated to be at least 20 Mt(N)/yr, may be the dominant source of NO_x to the global troposphere. Furthermore, since most of the anthropogenic sources of NO_x are located in the Northern Hemisphere, this new interpretation of the relative source strengths of this species favors a highly skewed asymmetric distribution of NO_x.
Geophys. Res. Lett., Paper 1L0381

Geodesy and Gravity

1910 Crustal movements
STRAIN AND DISPLACEMENT MEASUREMENTS FOR THE JUNE 9, 1980 VICTORIA, MEXICO EARTHQUAKE
D. Darby, E. Nyland (Institute of Earth and Planetary Physics, Department of Physics, University of Alberta, Edmonton, Canada T6G 2J1) F. Suarez, D. Chavez and J. Gonzalez

A microgeodetic network 22 km southeast of Est. Guadalupe Victoria, Baja California Norte, installed in late May 1980, has been resurveyed in an experiment that started 12 hours after the June 9, 1980 Victoria earthquake, which had an epicenter at 15 km depth about 5 km from the network. The resurvey was complete by June 13. Both the initial observations and the resurvey were done with HP3800 distance meter equipment. Some angular control was provided with a Wild T3 theodolite. The network underwent a compressive strain of 7±3 micro strain essentially parallel to the Cerro Prieto fault about the time of the earthquake. Strains of this size are associated with simple dislocation models of earthquakes of this magnitude. Its direction appears to be anomalous however. This may indicate compression related to soil liquefaction processes or strain near the end of the slip plane.
Geophys. Res. Lett., Paper 1L0178

1910 Crustal movements
GEODETIC STRAIN MEASUREMENTS IN WASHINGTON
J.C. Savage (U.S. Geological Survey, 345 Middlefield Road, M/S 77, Menlo Park, CA 94025), M. Lisowski, and W.H. Prescott

Two new geodetic measurements of strain accumulation in the state of Washington for the interval 1972-79 are reported. Near Seattle the average principal strain rates are 0.07±0.03 μstrain/a N19°W and –0.13±0.02 μstrain/a N71°E, and near Richland (south central Washington) the average principal strain rates are –0.02±0.01 μstrain/a N36°W and –0.04±0.01 μstrain/a N54°E. Extension is taken as positive, and the uncertainties quoted are standard deviations. A measurement of shear strain accumulation (dilatation not determined) in the epoch 1914-66 along the north coast of Vancouver Island by the Geodetic Survey of Canada indicates a marginally significant accumulation of right-lateral shear (0.06±0.03 μ rad/a) across the plate boundary (N40°W strike). Although there are significant differences in detail, these strain measurements are roughly consistent with a crude dislocation model that represents subduction of the Juan de Fuca plate. The observed accumulation of strain implies that large, shallow, thrust earthquakes should be expected off the coast of Washington and British Columbia. However, this conclusion is not easily reconciled with either observations of elevation change along the Washington coast or the focal mechanism solutions for shallow earthquakes in Washington. (Geodetic strain, Washington)
J. Geophys. Res., Red, Paper 1B0295

1910 Crustal movements
THE DETERMINATION OF DISPLACEMENT FIELDS FROM GEODETIC DATA ALONG A STRIKE SLIP FAULT
W. Prescott (U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA. 94025

Observations of angles or distances between stations of a geodetic network are commonly used to infer information about the movement of the surface of the earth. The absence of any observations external to the network leads to an ambiguous displacement field. Existing techniques for eliminating this ambiguity are all unsatisfactory in some respect. The best technique, an 'inner coordinate solution', is not appropriate for networks located in a strike slip fault environment. The inner coordinate solution zeros the rotation of all stations about their center of mass. Along a strike slip fault like the San Andreas, however, motion normal to the fault is less likely than motion parallel to the fault.

The solution presented here, an 'outer coordinate' solution, finds the rotation of the network that minimizes the components of displacement normal to the fault. Since motion along a strike slip fault is generally expected to be parallel to the fault, the displacements obtained with the outer coordinate solution are more reasonable than those obtained with other techniques.

Examination of a trilateration network near San Francisco Bay demonstrates the large effect that the choice of adjustment technique can have on the inferred relative motion of the two sides of the fault. The inner coordinate solution gave a rate of about 1 mm/year whereas the preferred outer coordinate solution rate was 36 mm/year.
J. Geophys. Res., Red, Paper 1B0367

1910 Crustal movements
POSTSEISMIC REBOUND DUE TO CREEP OF THE LOWER LITHOSPHERE AND ASTHENOSPHERE
S. Cohen (Geodynamics Branch, Goddard Space Flight Center, Greenbelt, MD 20771)

Post seismic surface deformations are attributed to the inelastic flow of the sub-crustal regions of the earth following an earthquake. A multilayer representation of the earth's rheological properties is used in conjunction with a finite element computational scheme to calculate time-dependent displacements and strains subsequent to a strike-slip earthquake. The deviatoric stress-strain relation for the upper-most layer is assumed elastic. Lower layers are assumed to be, in order of increasing depth a standard linear, three-element, viscoelastic solid; a linear viscoelastic fluid; and another elastic solid. Physically these layers correspond to the upper lithosphere, lower lithosphere, asthenosphere, and lower mantle, respectively. Elastic dilatational properties are assumed throughout. Appreciable postseismic displacements, possibly approaching meters for large earthquakes, arise from the viscoelastic relaxation following the sudden coseismic slip. Furthermore, compared to the simpler case of an elastic lithosphere over a viscoelastic asthenosphere the near-fault postseismic shear strain is increased, by a factor of two or more in some cases, by the presence of a viscoelastic lower lithosphere. Also the duration of post-seismic straining is increased if the viscosity of the lower lithosphere is greater than that of the underlying asthenosphere.
Geophys. Res. Lett., Paper 1L0418

1930 High-order harmonics of the gravity potential field
SAMPLING FUNCTION AND FINITE ELEMENT METHOD REPRESENTATION OF THE GRAVITY FIELD
H.F. Schmidt (Deutsches Geodätisches Forschungsinstitut, Zentralleitung, Arcisstr. 21, D-8000 München 2, W.-Germany)

After introducing the fundamental method of interpolation and approximation of functions using sampling functions, a method of sampling functions for the representation and determination of the earth's gravity field – based on spherical harmonics and an arrangement of sampling points on a sphere – is shown and discussed. As a result, high resolvable global sampling function models for the gravity field on the base of spherical harmonics show unsolvable problems at present, because of numerical difficulties and the problem to define practically nearly equidistant sampling point distribution on a sphere.

Additionally, this method of sampling functions representation is compared with the finite element method having in view the interpolation and modelling of geodetic and geophysical problems. The advantage of the finite element method can be seen in its flexibility with respect to the size and shape of the applied elements to represent even complex structures and its possibility to establish – as an example – a global as well as a local model of the gravity field of the earth.
Rev. Geophys. Space Phys., Paper 1R0331

The Enigma of Lunar Magnetism

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Introduction

The results of the Apollo program have given us an intriguing but very inadequate glimpse of the pervasive magnetization that characterizes the lunar crust. Returned sample studies, surface magnetic field investigations, and analyses of orbital measurements have provided useful constraints on the nature of the magnetization, but in retrospect, more questions have been raised than have been answered.

Perhaps the single most important of these questions concerns the origin of the magnetizing field. A simple possibility suggested from the outset is that the moon once possessed an intrinsic global magnetic field which originated in a small, formerly molten iron core. The existence of such a field, if verified, would have extreme implications for our understanding of lunar, and hence planetary, thermal evolution. However, clear evidence for more than a superficially magnetized crust has not emerged from the data analysis. Thermoremanent magnetization itself has been difficult to identify unambiguously in samples of the lunar regolith, partly because of their complicated impact histories. Surface and orbital measurements show magnetic anomaly signatures apparently associated with surficial material, such as basin ejecta, and not with deep-seated structures as expected from slow cooling in the presence of a steady magnetic field. Alternative suggestions for the origin of the magnetizing field have primarily involved local generation mechanisms. Of these, those that employ impact processes to briefly but strongly amplify the weak interplanetary magnetic field seem most reasonable in view of (1) the obvious bombardment history of the moon and (2) the association of some mapped anomalies with basin ejecta. In particular, impacts of cometary bodies, which normally possess large partially ionized atmospheres capable of strongly compressing a weak ambient magnetic field, have been mentioned most in this context.

The purpose of this contribution is to briefly assess our current understanding of the nature of lunar crustal magnetization, with emphasis on properties that may provide basic clues to its origin. Brief discussions of returned sample studies and surface magnetic field investigations are provided (for general reviews, see *Fuller* [1974] and *Dyal et al* [1974] respectively), but emphasis is placed on orbital studies that have not been completely reviewed elsewhere.

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Cover. Lunar orbiter photograph of the Van de Graaff-Aitken region, on which have been superimposed circles which represent the surface locations and scale sizes of the stronger magnetic anomaly sources of the region [*Hood et al.*, 1978b]. Also shown are projections of the inferred directions of magnetization for each source onto the lunar surface. The projections are long or short, depending on the estimated dipole moment per unit area, and the angle made by each vector with the surface is indicated.

Returned Sample Data

As deduced from a variety of magnetic property experiments, the main magnetization carrier in lunar rocks is metallic iron alloyed sometimes with small percentages of nickel and cobalt [e.g., *Nagata et al.*, 1972]. As shown in Figure 1 (upperhalf), among the returned samples the breccias and soils are significantly more enriched in metallic iron than are igneous materials such as mare basalt [*Housley et al.*, 1970; *Strangway et al.*, 1973a]. Moreover, as indicated in Figure 1 (lowerhalf), iron grains within the breccias and soils are often in the single-domain size range and therefore retain a much stronger magnetic remanence than the multidomain iron in the basalts. Consistent with these properties, the highest levels of stable natural remanent magnetization (NRM), about 10^{-4} G-cm^3/g, were reported for some classes of breccias and soils, while the mare basalts were characterized by levels that typically amounted to 2×10^{-6} G-cm^3/g or less. The stronger magnetism of the breccias and soils has been attributed to generation within these materials of metallic iron during impacts. This generation takes place via the reduction of iron oxides and silicates already present. Both impact-associated shock [*Cisowski et al.*, 1974] and heat [*Pearce et al.*, 1972] have been proposed as possible causal mechanisms.

Uncertainties in our knowledge of the generation of ferromagnetic material in lunar rock during impacts, together with the probably complicated impact histories of returned lunar samples, have made interpretations of the observed NRM, with respect to the origin of the magnetizing field, much more difficult. *Collinson* [1978] considers that the primary NRM of lunar basalt rock is most commonly thermoremanent magnetization (TRM), acquired at the time of extrusion onto the surface, but that the primary NRM has been subsequently modified, sometimes severely, by impact shock. *Fuller et al.* [1979] conclude that the observed magnetic properties of certain mare basalts are not consistent with a primary stable remanence of thermal origin and that a majority of the observed NRM is most probably a shock remanent magnetization (SRM) acquired during successive meteoroid impacts. These issues are obviously of central importance in understanding the nature of the magnetization process, and additional efforts to resolve them are underway at several laboratories.

Whether the primary remanence is TRM or SRM, the problem of the origin of the magnetic field(s) in which the magnetization was acquired remains. Attempts to measure the ambient field intensity at the times of formation of lunar samples have been difficult and controversial, partly because of experimental problems, partly because of the aforementioned complicated histories of the samples, and partly because of our incomplete understanding of rock magnetism. Nevertheless, there is some agreement that fields on the lunar surface of as much as one Oersted are required to explain the observed NRM of at least some samples [*Fuller*, 1978]. *Stephenson et al.* [1974] consider that the required intensities are consistent with the early proposal by *Runcorn et al.* [1970] (and others) that a former global lunar magnetic field, generated by dynamo action in a once active lunar core, is responsible for the primary NRM but that secondary magnetizations were later acquired by poorly understood mechanisms. The differing NRM properties and paleointensity estimates obtained for subsamples of a single specimen have led *Fuller et al.* [1979] to argue that a constant planetary-wide paleofield is unlikely and that transient magnetic fields, possibly generated during impacts [*Srnka*, 1977], would provide a more reasonable explanation for these properties.

Finally, mention should be made of the young (<200 m.y. old) soil breccia 70019 collected at the Apollo 17 landing site specifically for magnetic experiments. This sample exhibits NRM properties similar to those of other, usually much older, soil breccias; moreover, *Sugiura et al.* [1979] succeeded in performing a Thellier-Thellier paleointensity test on the sample's interstitial glass component, obtaining a value of about 2500 γ. Since the likelihood of a global lunar magnetic field in the recent past is negligible, the two possible explanations for this result, noted by the authors, are: (1) the sample was magnetized in a relatively strong local remanent field (fields exceeding 300 γ were detected at the Apollo 16 landing site, although no measurements were obtained at the Apollo 17 site; see below); (2) the sample was magnetized in a localized, transient magnetic field, possibly generated during the impact which produced the breccia.

Surface Magnetometer Data

As a first step toward extending the results of sample studies to infer large-scale characteristics of the magnetization, it is instructive to consider the intensities and directional behavior of local magnetic fields observed at the Apollo landing sites [*Dyal et al.*, 1974]. A minimal field strength of 3.4 ± 2.9 nT was detected on the edge of the Imbrium basalt plain at the Apollo 15 site, and a field of 38 ± 2 nT was detected at the Apollo 12 site on Mare Cognitum. Fields of 103 ± 5 nT and 43 ± 6 nT were measured at two locations separated by 1.1 km in the Fra Mauro region at the Apollo 14 site, and fields ranging in intensity up to 327 ± 7 nT were recorded near the Apollo 16 site in the Descartes highlands. Rapid changes in field intensity and direction were observed along a 7.1-km traverse at the Apollo 16 site.

The small scales of the magnetic fields detected along traverses at the Apollo 14 and 16 landing sites imply localized, near-surface sources. One interpretation of this finding is that an originally uniformly magnetized crust has been shattered and almost randomized by impacts. Alternatively, if some or all impacts caused magnetization of successive layers of ejecta materials, then the observed localization of remanent field sources could be due to superposition of layers with differing directions of magnetization.

The wide range in observed field intensities at different sites implies a strong dependence of the crustal field strength on local geologic setting. The Apollo 14 and 16 sites, where the strongest fields were measured, are respectively dominated by the Fra Mauro and Cayley formations. The Fra Mauro and Cayley units are interpreted by most analysts as primary and/or secondary basin ejecta, with at least the Fra Mauro produced at the time of the Imbrium impact [e.g., *Taylor*, 1975]. The Apollo 12 and 15 landing sites are located primarily in areas dominated by mare basalt. These results together with the stronger stable remanence exhibited by the breccias and soils in relation to that of igneous samples, such as the mare basalts, led *Strangway et al.* [1973b] to propose that especially coherently magnetized deposits of Cayleylike ejecta materials are likely to be major sources of large-scale magnetic anomalies that are detectable from lunar orbit.

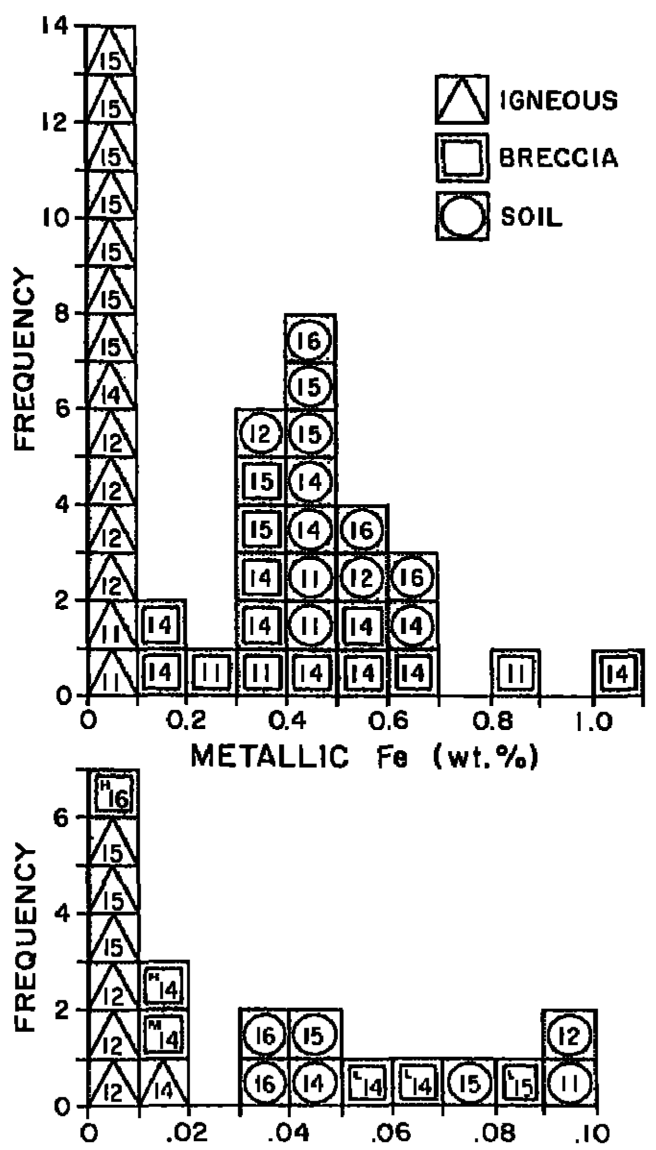


Fig. 1. (Top) Number of examined samples with metallic iron concentrations in specified ranges. The Apollo site number is indicated for each sample. (Bottom) Same for ratio of saturation remanent magnetization to saturation magnetization. [After *Strangway et al.*, 1973a]

Orbital Magnetometer and Charged-Particle Data

Orbital studies of lunar magnetism began with the Explorer 35 mission, which established the negligibly low value of the global dipole moment [*Sonett et al.*, 1967; *Ness et al.*, 1967; see also, *Russell et al.*, 1974] and indirectly detected crustal magnetized regions via localized compressions of the interplanetary magnetic field observed downstream from the moon [*Barnes et al.*, 1971; *Sonett and Mihalov*, 1972]. The initial direct detection of crustal magnetic anomalies with the Apollo 15 subsatellite magnetometer [*Coleman et al.*, 1972] led to an eventual application of both magnetometer and charged-particle data from the Apollo 15 and 16 subsatellites to the more detailed study of the distribution and properties of lunar surface magnetic fields.

Much of the early mapping of the direct subsatellite magnetometer data was restricted to measurements obtained within the relatively undisturbed plasma environment of the geomagnetic tail lobes [*Sharp et al.*, 1973; *Russell et al.*, 1975, 1977]. Later mapping concentrated on intervals when the moon was in the solar wind but the Apollo 16 subsatellite was at a low altitude in the lunar wake [*Hood et al.*, 1979a, b]. The possibility of mapping the distribution of lunar surface magnetic fields via their reflection of energetic electrons was first pointed out by *Howe et al.* [1974] and has been discussed in further detail by *Anderson et al.* [1975] and *Lin et al.* [1976]. Although the technique is indirect, it is complementary to the direct detection method because when the subsatellite was exposed to the solar wind or magnetosheath plasma, intervals are quite suitable for mapping, whereas the magnetometer data from these intervals are not. Finally, a study of compressions of the interplanetary magnetic field that was detected with the subsatellite magnetometers in which the locations of several large-scale magnetized regions were inferred has been reported by *Russell and Lichtenstein* [1975].

At least partly because of the restricted coverage of early magnetic anomaly maps produced from direct magnetometer measurements, the identification of major anomaly sources from this data set was not swift. One correlation of a quasi-linear surface magnetization feature found in electron reflection data on the near side with a long structural rille, Rima Sirsalis, was reported by *Anderson et al.* [1977], and quantitative estimates of the magnetization intensities required to explain the anomaly according to several possible models were made [*Srnka et al.*, 1979]. However, no firm con-

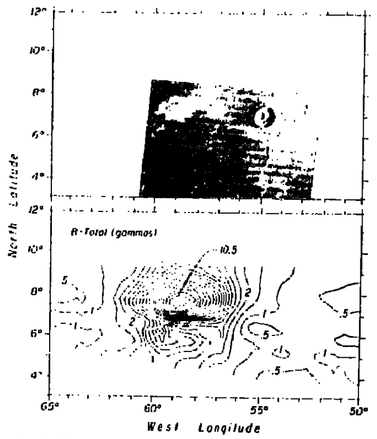


Fig. 2. Correlation of a relatively strong magnetic anomaly found in Apollo 16 subsatellite magnetometer data with a conspicuous medium-albedo marking on western Oceanus Procellarum, known as Reiner Gamma [*Hood et al.*, 1979a].

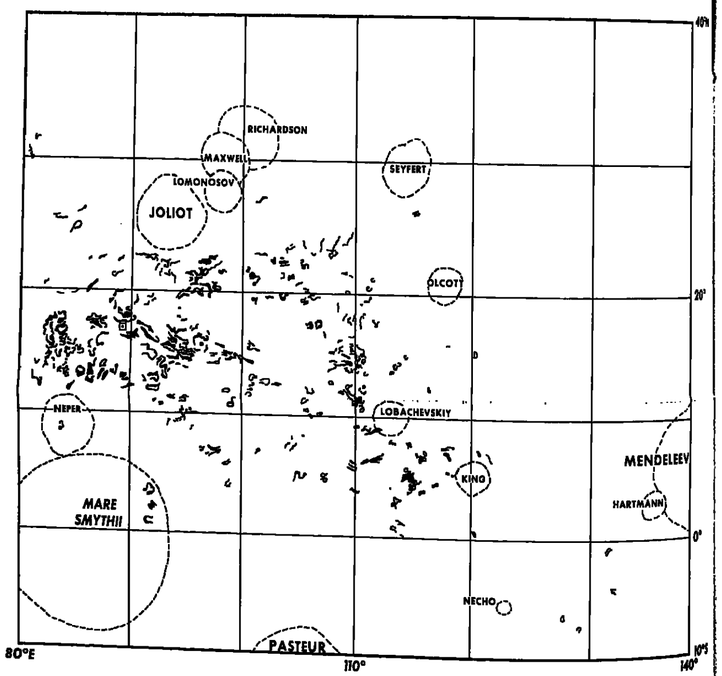
clusions as to the most probable source of the observed anomaly have been drawn [see also, *Anderson and Wilhelms*, 1979]. Further insight into the sources of large-scale anomalies came when direct Apollo 16 subsatellite magnetometer data that were collected at low altitudes over geologically less complex areas of the near side were examined [*Hood et al.*, 1979*a*, *b*]. Magnetic anomalies were found to be nearly absent over the western maria and over several large impact craters such as Copernicus and Kepler; anomalies were, however, detected over exposed segments of the Fra Mauro Formation and over areas dominated by the Cayley Formation. These results represent at least circumstantial evidence that favors *Strangway et al.*'s (1973*b*) ejecta deposit hypothesis, based on returned sample and surface magnetic field data. Further support came from a study of electron reflection maxima detected with the Apollo 16 subsatellite charged-particle instrument across the lunar far side in which the identified magnetized regions occur peripheral to large impact basins in areas where deposits of basin ejecta are observed or inferred [*Anderson and Wilhelms*, 1979]. This part of the orbital data is consistent with a relatively simple picture in which surficial deposits of ejecta from large meteoroid impacts constitute a major portion of magnetized material on the moon. Such a picture does not immediately allow an identification of the magnetizing field(s), but the possible importance of impact processes in either distorting an existing large-scale magnetic field or in generating short-lived fields of the required intensities is clear.

Less easy to explain via such a simple model are the higher-amplitude anomalies detected with the subsatellite magnetometers and charged-particle instruments. For many years, these anomalies were cited as possible evidence for a former long-term lunar magnetizing field, since it was assumed that rather large thicknesses of crustal material (cooling over long time intervals) must be coherently magnetized to produce anomalies detectable at subsatellite altitudes. Some light was cast on this issue when the strongest anomaly present in data from low-altitude passes of the Apollo 16 subsatellite across the near side was found to correlate exactly with the location of a peculiar swirllike albedo marking on western Oceanus Procellarum, known as Reiner Gamma (Figure 2). The absence of a detectable gravity anomaly and the superposition of the feature on mare basalt flows, materials that are elsewhere poorly magnetized, increases the probability that the magnetic anomaly is due to a thin surficial layer of strongly magnetized material. If the layer was deposited during an impact, then it may have formed and acquired its magnetization in a relatively short period of time. Thus, although other questions are raised (including the inferred high magnetization level of the source layer), the requirement of a long-term magnetizing field to produce strong crustal magnetic anomalies on the moon may be circumventable. Similar but much more extensive groups of Reiner Gamma-type swirls have been identified on available photographs in highland terrain on the far side (Figure 3). Four of the areas where swirls are most strongly concentrated are known to be anomalously magnetic in relation to a large fraction of the lunar surface [*Lin et al.*, 1980]. Most of the areas of especially intense crustal magnetism detected with the Apollo subsatellites can now be associated with general concentrations of swirls, although a one-to-one correspondence has been demonstrated, because of coverage limitations, only for Reiner Gamma.

The geologic origin of the Reiner Gamma-type swirls has been the subject of considerable debate, but the debate has not yet yielded agreed-upon constraints on the more general issue of the nature and origin of lunar crustal magnetization. *Hood et al.* [1979*b*] proposed that Reiner Gamma consists of unusually magnetic deposits of ejecta from secondary craters of the nearby large impact crater Cavalerius (age: ~ 3.2 b.y.). Preservation of the relatively high albedo of Reiner Gamma and some of the other swirls (those that are associated with impact craters older than about 1 b.y.) was ascribed to deflection of the solar wind ion bombardment by the strong magnetic anomaly [*Hood and Schubert*, 1980]. However, *Schultz and Srnka* [1980] point out that the swirls often contain dark lanes as well as bright patterns, that the bright swirls are strong forward reflectors in contrast with most crater rays, and that at least some of the swirls north of Mare Marginis appear to be associated with the relatively young (late Copernican) crater, Goddard A. Therefore, as an alternative to the crater ejecta hypothesis, these authors proposed that all of the swirls may be strongly magnetized residues of relatively recent collisions of the moon with one or more cometary comas. While cometary impacts may be viable candidates for providing strong magnetizing fields at the lunar surface [*Gold and Soter*, 1976], there are several difficulties with the cometary impact proposal for the production of the swirls. These have been noted by *Hood* [1980]. Other suggested mechanisms for producing the swirls, which predate the magnetics data, have been listed by *Schultz* [1975].

In addition to putting limits on the geologic nature and origin of magnetic anomaly sources, orbital studies using vector magnetometer data have attempted to determine, to a first approximation, directional properties of the magnetization as well. A knowledge of the latter as a function of position in the crust would of course place severe constraints on the orientation(s) and scale-size(s) of the lunar magnetizing field(s). Although source models for a given magnetic anomaly are in many respects nonunique, several assumptions can be made that yield probable estimates for the bulk direction of magnetization of the source. First, based on the several correlations of magnetic anomaly maxima with surface geologic units noted above, it can be assumed that sources are at or near the lunar surface; a reasonable source model is a uniformly magnetized disk with a finite radius to be determined by a fit to the data. Second, in the case of relatively isolated anomalies it can be initially assumed that the surface position of the source is directly beneath the total field maximum detected from orbit. This assumption is exactly valid only when the direction of magnetization of the source is precisely vertical or horizontal, so in practice, small adjustments from the initial position are necessary in the model-fitting procedure.

The only results reported thus far have been for a section of the lunar far side, in the region occupied by the craters Van de Graaff and Aitken [*Hood et al.*, 1978*a*, *b*]. As indicated in the cover figure, it was found that adjacent source regions in the studied area are most probably magnetized in very different directions. The only nonrandom characteristic of the inferred directions of magnetization claimed by *Hood et al.* [1978*a*, *b*] was a depletion in the north-south direction. However, *Runcorn* [1978, 1979] has calculated pole positions of an assumed internal magnetizing dipole that correspond to the inferred magnetization directions. Surprisingly, he finds a small but statistically significant clustering of these pole positions near 0° latitude, 90° and 270° east longitude. Furthermore, he finds that the pole positions that correspond to the strongest anomalies, i.e., those whose magnetization directions were probably determined most accurately, are more strongly clustered than the remainder of the pole positions. Runcorn then concludes that the results are most consistent with the lunar core dynamo hypothesis for the origin of the crustal magnetization, although polar wandering by approximately 90° must be simultaneously invoked.



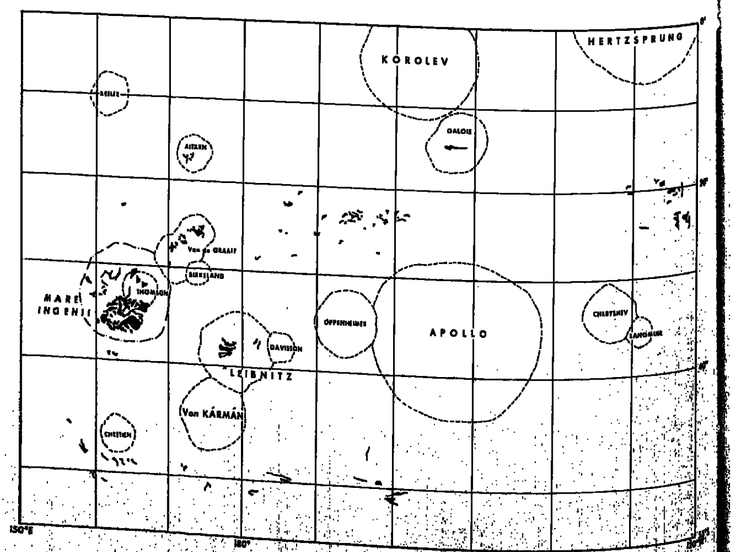


Fig. 3. Distribution of albedo markings morphologically similar to Reiner Gamma visible on available photographs of (a) the eastern limb and (b) the central far side as mapped by *Schultz and Srnka* [1980].

Since the far-side region considered in the model-fitting analysis was located near 180° longitude, the small clustering of pole positions near 90° and 270° found by Runcorn implies that the magnetization directions in the studied area must exhibit a small tendency to be more horizontal than vertical. A reexamination of the inferred directions shows that this is indeed the case as can be seen, in part, from the cover figure. The strong north-south depletion of the inferred magnetization directions, together with their lesser tendency to be more horizontal than vertical, does not necessarily require magnetization by a global magnetic field. Specifically, a compression of the interplanetary magnetic field (which normally lies parallel to the ecliptic plane) against the moon during impacts by bodies with partially ionized gaseous envelopes [*Gold and Soter*, 1976] could lead to similar directional properties. The highly inclined magnetization vectors required to explain observed anomalies on the far side could be understood by superposition of anomaly sources during successive impacts.

An obvious way to distinguish between these two possibilities is to determine bulk magnetization directions in other areas on the moon, preferably away from 0° and 180° longitude. During the past 2 years, contour maps of the subsatellite magnetometer data in several other regions have become available. Model-fitting procedures are currently being applied to these data.

Suggestions for the Future

The Apollo 15 and 16 particles and fields subsatellite missions were not designed to map the distribution of crustal magnetic anomalies on the moon. Although some excellent data were fortunately acquired within limited regions, optimization of orbit characteristics during a future mission would provide significant increases in coverage and resolution of both direct magnetometer measurements and indirect electron reflection measurements. Essentially, the orbit should be nearly polar with a low-altitude (about 30 km) periapsis near the antisunward position. A polar orbit would provide almost global coverage in contrast to the narrow equatorial bands sampled with the Apollo subsatellites. A 30-km periapsis altitude is required to adequately resolve the crustal magnetic field and is approximately equal to the separation between adjacent polar orbit tracks at the equator (the moon rotates about 1° during a 2-hour orbit). Location of the periapsis near the antisolar position is required to minimize solar-wind-associated plasma disturbances, which strongly affect the magnetometer measurements. Because of the existence of crustal gravity anomalies, which led to the demise of the Apollo 16 subsatellite, and because of the tendency for the periapsis to precess away from the antisunward position, which reduced the usefulness of most of the Apollo 15 subsatellite wake intervals, it is imperative that the spacecraft be capable of modifying its orbit from time to time during the intended mission lifetime.

In combination with additional photogeologic studies and other geophysical and geochemical measurements obtained from the same spacecraft, such a set of data would place more decisive constraints on the origin of lunar crustal magnetization. For example, if strong magnetic anomalies are associated with other Reiner Gamma-type swirls on the lunar far side that are demonstrably young, then the existence of transient magnetic fields, probably generated during impacts, would be more clearly indicated. Alternatively, if other anomalies are demonstrated to be associated with deep-seated structural features, then the former existence of a global lunar magnetic field would become a more viable hypothesis. It is important to emphasize that more than one process may have been responsible for generating magnetic fields at the moon's surface during its history and only when a complete global survey has been obtained will final conclusions become possible.

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News

Space Transportation

The U.S. space shuttle ushers in a unique flight research program that supports NASA's advanced (21st century) space transportation program.

The space shuttle serves as a 'flying test bed,' carrying experiments to measure orbiter flight performance parameters during launch, booster, orbit, atmospheric reentry, and landing mission phases.

The flight research experiments will aid the development of concepts such as single-stage-to-orbit, heavy-lift launch vehicles and orbital transfer vehicles. These vehicles could deploy and service large, automated, human-operated, multifunctional satellite platforms and an inhabited permanent facility in Earth orbit.

Two experiments, called the Orbiter Experiments Program, were included with the flight of space shuttle *Columbia*. The Aerodynamic Coefficient Identification Package (developed by the Johnson Space Center, Houston) on board *Columbia* will collect aerodynamic data during all orbiter major flight phases. The Infrared Imagery of Shuttle (developed by the Ames Research Center, Mountain View, Calif.) experiment, located aboard a NASA C-141 aircraft, will gather high-resolution temperature maps of the orbiter's thermal protection system during its maximum entry heating phase. The aircraft will underfly the *Columbia* as it returns from space for landing at the mission's end.

The results will advance aerodynamic theories, ground test methods, and other techniques used to predict and simulate performance of aerospace vehicles. The data will also be used to support verification of the current space shuttle orbiter's design and to aid in evolutionary improvements to the space shuttle. [Source: NASA]—*PMB*

Extractive Metallurgy Program Funded

In an effort to concentrate research on ore dressing and metal production, the National Science Foundation (NSF) formed a new basic research program as a part of its Chemical and Process Engineering Division. This program will be under the auspices of NSF's Engineering Directorate. Research is to be supported on every step of extractive metallurgy, from mining to processing to production, and even to reprocessing and disposal. Budgeting for the new program is expected to be on the order of $1.2 million for fiscal year 1981.

A program of this nature was apparently considered seriously by the Carter administration as a joint Department of Interior-private industry project of considerable size. Then-Secretary of Interior Cecil Andrus evidently did not support the program, but there is wide agreement throughout the mineral industries and the university community that such research is badly needed for the U.S. to compete. A joint program could benefit by cutting across the many difficult regulations that now are blamed for slowing research in minerals processing in this country.

The newly announced program will probably be conducted as a collaborative effort between universities and industry, but under the NSF, it will be on a smaller scale than that considered by the Carter administration. Director of the funding program, T. Mukherjee, plans a materials science approach. Metal production suffers in the United States by being energy intensive and generally less efficient than in many parts of the world. A strong research effort is needed and fits well in NSF's new Engineering Directorate.—*PMB*

Dynamics Explorer Twins

Two spacecraft that will ride piggyback into orbit next July are currently undergoing vigorous prelaunch testing at the Goddard Space Flight Center, Greenbelt, Md. Called Dynamics Explorer (DE) -A and -B, the twin satellites are scheduled to be stacked together and placed into coplanar polar orbits by a Delta 3913 launch vehicle from the Western Space and Missile Center, Lompoc, Calif., on July 31.

Their mission will be to explore the boundary region between Earth and space that affects the atmosphere, auroral displays, radio transmissons, and perhaps climate and weather. Solar radiation and the solar wind have a dynamic impact on the near-Earth environment, the results of which affect the state of the atmosphere, ionosphere, magnetosphere, and the more familiar phenomena—weather, auroral displays, and radio disturbances.

Prior spacecraft, such as the Atmospheric Explorers, have provided new information on solar radiation upon the lower thermosphere and upper atmosphere. The ISEE (International Sun-Earth Explorer) program has provided additional new information on interactions between the solar wind and Earth's magnetic field; however, adequate knowledge does not exist on the interactions between the two regions. The Dynamic Explorer program is designed to supply such knowledge—specifically, the strong interaction processes coupling the hot, tenuous, convecting plasmas of the magnetosphere and the cooler, denser plasmas and gases corotating in Earth's ionosphere, upper atmosphere, and plasmasphere.

To accomplish this, the project will provide a central data processing and analysis system so that each investigator on the science team can display geophysical data from all spacecraft instruments. In their polar coplanar orbits, one satellite (DE-B) will have a perigee sufficiently low (305 km) for neutral composition, temperature, and wind measurements.

Its apogee will be sufficiently high (1300 km) to provide a

(*News cont. on page 164*)

Lonnie L. Hood is a research associate at the Lunar and Planetary Laboratory of the University of Arizona in Tucson. He received his Ph.D. in geophysics and space physics in 1979 from the University of California at Los Angeles, where his research work involved analysis of Apollo subsatellite magnetometer data (under the direction of P. J. Coleman, Jr., and C. T. Russell) and theoretical studies of electromagnetic induction in the moon and Mercury (under the direction of G. Schubert). Current research includes analysis of simultaneous Apollo 12 surface and Explorer 35 orbital magnetometer data (in collaboration with C. P. Sonett and F. Herbert) and studies of problems relating to outer-planet magnetospheres.

(News cont. from page 163)

lifetime greater than 1½ years and to allow measurements above the interactive regions for superthermal ions and plasma flow measurements of the magnetospheric field lines.

The second spacecraft (DE-A) will be placed into a highly elliptical orbit having an apogee of 24,875 km to allow for global auroral imaging, wave measurements in the middle of the magnetosphere, and crossings of auroral field lines at several Earth radii.

The DE-B (low mission) has six 3-cm-diameter flexible stem antennas 10 m long and a single rigid boom 6 m long. These external antennas will collect data for the scientific instruments on board.

The solar cell arrays mounted on the 136-cm-diameter spacecraft body will supply the satellite with electrical energy that can be delivered directly to the scientific instruments or stored in nickel-cadmium batteries as required.

DE-A is spin stabilized; its pitch, or spin axis having a spin rate of 10 rpm, while the DE-B spacecraft is three-axis stabilized with its pitch axis controlled to continually point toward Earth's surface. Configurations of both spacecraft are designed to minimize unbalancing torques created by atmospheric drag encountered in space.

Tracking, command, real-time, and recorded data will be provided by NASA's Space Tracking and Data Network; the NASA World-Wide Communications System, NASCOM; and the DE Operations Control Center at Goddard. [Source: NASA]—*PBM*

Antarctic Meteorite Symposium

The Sixth Antarctic Meteorite Symposium was held in Tokyo, Japan, February 19 and 20. Sponsored by the National Institute of Polar Research, the symposium brought Japanese scientists together with several Americans and two Chinese to discuss current research on meteorites, emphasizing research on meteorites collected in Antarctica. The symposium, now an annual event, owes its origin to the recent success of Japanese polar scientists in collecting large numbers of meteorite specimens in the Yamato Mountains, a program now successfully emulated by U.S. parties to the Allan Hills and adjacent regions.

Forty-seven papers were delivered orally, primarily in Japanese (the abstract volume was printed in English), on subjects that included location, field collection, and curation of specimens (6); classification and description of meteorites from Yamato Mountains and Allan Hills (14); mineralogical and petrological studies (8); chemical and isotopic studies (8); exposure ages and terrestrial ages of Antarctic meteorites (3); magnetic and other physical properties (3); and Chinese meteorites (3).

The contributions represented primarily the work of Japanese scientists (a small part of it in collaboration with workers in the U.S.). The Japanese program is strong in mineralogical-petrological investigations, with a small but growing number of geochemists and geophysicists participating. Despite the mineralogical skills of the Japanese participants in Antarctic meteorite research, basic description of the Japanese collection is not far advanced, in part because of the magnitude of the collection (nearly 4000 specimens) but also because there are few Japanese petrologists who previously have studied meteorites. Efforts are being made to address that problem and to expand the Japanese Antarctic Meteorite Program to international status. As more scientists from outside Japan learn of the collection, the amount of research reported at future Antarctic Meteorite Symposia will certainly grow. Information on the Proceedings of the 6th Antarctic Meteorite Symposium, details of future symposia, and catalogs of the Yamato Meteorite Collection (compiled by K. Yanai) can be obtained from T. Hagata, National Institute of Polar Research, Kaga, Itabashi-ku, Toyko 173, Japan.—*PMB*

New Publications

Atmospheric Physics

J. V. Iribarne and H.-R. Cho, D. Reidel, Boston, xii + 208 pp., 1980, $15.95.

Reviewed by Franklin I. Badgley

This compact book packs a great deal of information into its 212 pages and presents it in a straightforward, comprehensible manner. According to the authors it is intended as a textbook for a university course at a second or third year level for students who have had a first-year general physics course and a knowledge of elementary mathematics. Judging from the content, this math should include a working knowledge of both integral and differential calculus. Some knowledge of chemistry is also essential for understanding the material on that subject.

The text is divided into seven chapters entitled 'General Description,' 'Atmospheric Chemistry,' 'Radiation,' 'Atmospheric Thermodynamics and Vertical Stability,' 'Cloud Physics,' 'Atmospheric Electricity,' and 'Atmospheric Dynamics.' As the authors point out, the sections on chemistry and electricity are somewhat unorthodox but may appeal to instructors of certain courses or may be omitted if desired.

The material is well handled, and certain topics such as radiation and atmospheric electricity are presented as clearly and as concisely as is possible at the level for which they are written. Less satisfactory is the final chapter on atmospheric dynamics which attempts to cover motions of all scales, from global to micro, and from both mathematical and descriptive viewpoints, in 47 pages.

Particularly, in the first part of the book, some important equations are given without derivation; for example, the reflection of electromagnetic waves, the Clausius-Clapeyron equation, Planck's law, and related laws concerning blackbody radiation. It is improbable that the student with the preparation specified above would have encountered these previously so it is a matter of pedagogical preference as to whether to stress the implications of these laws without investigating their sources, as the present authors do, or to cover less material with more stress on derivations. In other instances, such as the derivation of expressions for dry and saturated adiabatic lapse rates and of the equations of motion and continuity, the mathematical developments are made concisely, understandably, and with a suitable blend of physical insight and mathematical approximation.

Numerous questions and problems are given at the end of each chapter, some easy, some challenging enough to offer teachers and students a means of enlarging the chapter content. There seem to be few errors. A good bibliography is given. Answers to some of the questions and problems are included. One subject that is not treated but which would fit well with those which are included is atmospheric optics.

It is difficult to know for just what type of audience the book would be exactly suited. It is definitely not for the casual arts or literature student who wants easy access to some knowledge of the atmosphere, nor in this reviewer's estimation is it the best choice as an introduction for a person intending to specialize in the field, although it could be adapted to the latter use. Rather it would most closely meet the requirements of a student well trained in basic science and math who intends to specialize in some field such as engineering, astronomy, or oceanography and who wants more than a cursory insight into the physical nature of the atmosphere, its solved and unsolved problems, and the techniques available for attacking them. Anyone contemplating a course for a group of such qualified students should give serious consideration to this carefully written text.

Franklin I. Badgley is with the Department of Atmospheric Sciences, University of Washington, Seattle, Washington.

Classified

Meetings

Ocean Sciences: AGU/ASLO Joint Meeting

A joint meeting of the American Geophysical Union's Oceanography Section and the American Society of Limnology and Oceanography will be held February 16–19, 1982, in San Antonio, Texas. The El Tropicano Hotel is headquarters for the meeting, with additional housing available at the St. Anthony and the Gunter hotels.

The Call for Papers, soliciting contributed papers from AGU and ASLO members, will be issued later this spring. All abstracts must be submitted according to AGU format and guidelines. The deadline for abstracts will be in November. Information on publication will be included in the call for papers.

Special Sessions

- Ocean Climate and Biological Productivity Connections
- Overview of Large Oceanographic Projects
- Biology and Physics of Gulf Stream Rings
- Relations Between Biology and Circulation in the Gulf of Mexico
- Geological Effects of Ocean Circulation
- Anthropogenic Inputs to the Ocean: Diverse Points of View
- Processes and Resources of the North Pacific Shelves
- Small Lake Limnology
- Marine and Freshwater Bioturbation
- Ocean-River Interaction: Sedimentation and Chemistry
- Particle Fluxes in the Water Column and Benthic Boundary Layer
- Relations between Mesoscale Physical and Biological Processes
- Coastal Processes
- Biological and Physical Measurement Techniques
- Microscale Processes and Effects on Biota
- Physics and Biology of Ice Edges

Program Committee

Convenors: Worth D. Nowlin, Jr., Department of Oceanography, Texas A&M University, College Station, TX 77843, (713) 845-2947; Richard W. Eppley, Institute of Marine Resources, A-018, S.I.O., University of California at San Diego, La Jolla, CA 92093, (714) 452-2338 (office), (714) 452-3194 (secretary).

Members: Charles D. Hollister, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, (617) 548-1400; Peter Jumars, Ocean Science and Technology Division, Office of Naval Research, 800 N. Quincy Street, Arlington, VA 22217, (202) 696-4590; Claire Schelske, Great Lakes Research Division, University of Wisconsin, 2200 Bonnie Steel Boulevard, Ann Arbor, MI 48109, (313) 764-2422; and Karl Turekian, Geology Department, Yale University, Box 2161, Yale Station, New Haven, CT 06520, (203) 436-0377.

Housing

El Tropicano Hotel	St. Anthony Hotel	Gunter Hotel
Single $37	Single $44	Single $35
Double $47	Double twin $60	Double $41
	Double/double $80	Additional person
	King $78	$5.00

If you are not an AGU or ASLO member, write Meetings, AGU, 2000 Florida Avenue, N.W., Washington, D.C. 20009 and ask to be placed on Ocean Sciences Joint Meeting mailing list.

Erosion-Sedimentation Processes in Mountainous Terrain

The spectrum of processes influencing erosion and sedimentation is greatly enlarged in mountainous areas as compared to lowlands. Accordingly, much of the knowledge gained from studies on lowlands has limited application in mountainous regions. A symposium to review erosion-sedimentation processes in mountainous terrain is scheduled for the 1981 Fall Meeting of the American Geophysical Union. The meeting will be held in San Francisco during the week of December 7–11, 1981. Four major areas of interest will be considered: (1) surface erosion processes; (2) mass erosion processes; (3) channel processes; and (4) effects of land uses. Papers dealing with individual processes or combinations of processes or modeling of responses will be considered.

A copy of the abstract must be sent to the symposium chairman by August 15 at the following address: Walter F. Megahan, Forestry Sciences Laboratory, USDA Forest Service, 316 East Myrtle Street, Boise, ID 83702.

Details regarding the meeting and the submission of abstracts will be announced in *Eos* in June; similar information can be obtained by writing Fall Meeting, American Geophysical Union, 2000 Florida Avenue, N.W., Washington, D.C. 20009.

An original and two copies must be sent to AGU at the above address by the Fall Meeting Abstract deadline—September 16, 1981.

Rainwater Cistern Systems

The University of Hawaii's Water Resources Research Center and AGU will cosponsor the International Conference on Rainwater Cistern Systems, scheduled for June 15–18, 1982, in Honolulu, Hawaii. The objective of the conference is to gather past and current knowledge of rainwater cisterns, including rainfall analysis, catchment area, storage cisterns, water quality control, water use policy, and risk analysis. Also to be included are discussions of urban water management and the impacts of cisterns on society, the environment, and energy conservation. Integration of the rainwater cistern systems with existing water supply and storm drainage systems will also be explored.

For additional information, contact Yu-Si Fok, General Conference Chairman, Water Resources Research Center, University of Hawaii, 2540 Dole Street, Honolulu, HI 96822 (telephone 808/948-7298).

Hydrometeorology Symposium

The American Water Resources Association will sponsor an international symposium on hydrometeorology on June 13–17, 1982, in Denver, Colorado. In addition to paper sessions and panel discussions, poster sessions and field trips are planned. An exhibit of international hydrometeorology equipment, books, and services is also expected.

The technical program will cover droughts, flood forecasting, climatic trends, weather modification, acid precipitation, conflicts in hydrologic/meteorologic analyses, and hydrometeorological aspects of energy development. Offered and invited papers will be included in the program.

Additional details on the symposium may be obtained from General Chairman A. Ivan Johnson, Woodward-Clyde Consultants, 2909 West 7th Avenue, Denver, CO 80204.

Petroleum Colloquium

The Canadian Petroleum Association will sponsor Colloquium III on Petroleum Mapping and Surveys in the '80's in Banff, Alberta, on October 14–16.

On the session agenda are discussions of current special surveying techniques, present and future techniques for navigation and offshore positioning, new techniques for mapping and charting, federal government surveying and mapping developments and requirements in the coming decade, and the impact of new scientific mapping and surveying developments on the petroleum industry.

To receive additional information about the colloquium, or to register in advance, write to Liz Hampton, Canadian Petroleum Association, 1500, 633 Sixth Avenue, S.W., Calgary, Alberta, T2P 2Y5, Canada.

AGU

Membership Directory Corrections

Please note the following corrections or omissions from the Membership Directory published in the November 4, 1980 *Eos*.

Benedito P. F. Braja, Jr., Department de Hidraulica—EPUSP, P.O. Box 8174, Sao Paulo, SP, Brazil 05568, (M-78-H).

Robert F. Cockerham, U.S. Geological Survey, Mail Stop 77, 345 Middlefield Road, Menlo Park, California 94025, (M-70-T).

Stephen A. Cooperman, Department of Earth/Space Sciences, University of California at Los Angeles, Los Angeles, California 90024, (O): 213-825-4363, (H): 213-893-8249, (S-79-P).

Irene Fischer, 301 Philadelphia Avenue, Takoma Park, Maryland 20012, (F-56-G).

James T. Peterson, NOAA, RL3-335, 325 Broadway, Boulder, Colorado 80303, (O): 303-497-6668, (H): 303-530-4695, (M-79-M).

William W. Sager, Hawaii Institute of Geophysics, 2525 Correa Road, Honolulu, Hawaii 96822, (O): 808-948-8972, (H): 808-946-7456, (S-79-GP).

Gordon S. Stewart, Seismological Laboratory, California Institute of Technology, Pasadena, California 91125, 213-795-6811, X2958, (ST-75-S).

William Thordarson, 1020 15th Street, 8G, Denver, Colorado 80202, (M-79).

Michael A. Weissman, Flow Research Company, 21414 68th Avenue South, Kent, Washington 98031, 206-872-8500, (M-79-O).

Those members who joined before April 1979 have secondary sections of Seismology and Meteorology switched.

SAIL INTO Baltimore

AGU Spring Meeting

May 25–29

Session Highlights

● Tectonophysics

Large-Scale Thin-Skin Tectonics (cosponsored by Seismology)

Includes investigations and structural analyses of thin-skin-style deformation in regions of both compressional and extensional tectonism. Geologic and seismic evidence for active decollement-style faulting and geophysical and geologic data on ancient analogues will be discussed together with the question of reactivation of decollements. Regional studies span the globe, including investigations in the Himalayas, Aleutian trench area, big bend area of the San Andreas, Taiwan, Turkey, the Alps, the Apennines, the Appalachians, the Cordilleran fold and thrust belt, and the Basin and Range province. (A full day session on Wednesday followed by a brief business meeting and beer.)

Tectonics of Venus and Earth: A Comparison (cosponsored by Planetology)

Pioneer Venus has provided earth scientists with their first glimpse of the surface of the earth's sister planet. Other data collected by the Pioneer spacecraft on the gravity field of Venus and the composition of its atmosphere provide additional constraints on models of planetary structure and evolution. Analysis of this data clearly indicates that there are significant differences between current styles of global tectonic deformation on these two planetary bodies. This special session will review the fundamental differences between the structure and composition of Venus and the earth. It will also consider various models of tectonic and planetary evolution that have been proposed to account for these differences. Specific topics to be discussed include mantle convection, isostasy, plate tectonics, and continental nucleation and growth. (Monday, P.M.)

Illinois Deep Hole Project (cosponsored by VGP)

Preliminary results of investigations in a privately drilled, continuously cored 1.6-km-deep drill hole in northern Illinois made available to the scientific community. This hole penetrated approximately 1 km of crystalline basement, affording detailed studies of the petrography, chemistry, deformation history, and isotopic geochronology of the Precambrian that comprises the basement, as well as deep measurements of the rock mass permeability, heat flow, and state of stress in this currently tectonically stable interior region. (Monday PM)

● Seismology

A day-long special session Wednesday on New Frontiers in Earth Structure is devoted to the seismic transmission problems of anisotropy, scattering, and Q. The topics discussed include mantle anisotropy and its geodynamic implications, apparent and real Q in the short-period passband, and in situ Q measurements. The controversial nature of these studies should stimulate some lively discussions. At the special session on Refraction and Reflection, Tuesday morning, the latest results from COCORP deep crustal soundings will be presented along with theoretical studies of wave propagation in oceanic structure and travel time inversions. A Monday afternoon session on Seismicity and Tectonics will feature a reassessment of the motion between the Caribbean and North American plates, based largely on seismological evidence. Also to be presented at that session is an asperity model for global variations in the modes of subduction. On Tuesday afternoon a session on the Seismic Source will emphasize moment tensor representations of large earthquakes, with a particularly interesting paper on complex earthquakes modelled as two or more large events with different mechanisms separated in space and time.

● Volcanology, Geochemistry, Petrology

Arcs and Ophiolites

This session will concentrate on geochemical and isotopic evidence concerning the origin of arc-related volcanism, including the relation between subduction and the chemistry of arc volcanic rocks, and the origin of ophiolites. An important question addressed by several of the papers is that of the possibility that ophiolites represent oceanic crust from more than one geochemical environment. (Monday, A.M.)

Kimberlites and Other Strange Bodies

This section concentrates on the petrology, geochemistry, and origin of kimberlites, but it also includes papers on carbonatites, ultramafic bodies, and xenoliths. The session should appeal especially to those who are interested in data and ideas concerning samples from deep-seated environments. (Monday, P.M.)

Precambrian Evolution of the Earth

The two special sessions on the Precambrian Evolution of the Earth will concentrate on the history and processes from the initial accretion to the formation of the continental crust. The origin of the earth will be discussed within the larger context of the origin of the solar system and evidence about formation from the study of meteorites. Subsequent topics to be discussed will include accretions, thermal evolution, convection in the primitive earth, chemical zonation and development, and age and development of continental crust. (Tuesday)

Silicate Melt Structure and Crystallization Processes in Igneous Rocks

A full day will be devoted to these special sessions. They will bring together workers in the fields of crystal chemistry and petrology to present review papers as well as papers discussing new methods and data. Topics will include the structure of geologically important silicate melts, methods of determining melt structure, applications of the concepts of melt structure to petrologic problems, processes of controlled crystal growth from silicate melts, effects of nucleation and growth on the textures and mineral compositions of igneous rocks, and solubility of volatile components in silicate melts. (Wednesday, A.M.)

Seafloor and Ocean Island Volcanic Rocks

The source geochemistry and mechanisms of ridge crest midplate volcanism still remain mysterious in spite of a considerable body of data on rocks from these environments. The papers in this session will focus primarily on magma generation process at midocean ridges and geochemical comparison of MORB and volcanic rocks from oceanic islands. Several papers deal with the geochemistry of aseismic ridges and lavas produced from subducted ocean crust. (Wednesday, A.M.)

Isotope Geochemistry and Geochronology

This session will include a variety of papers of interest to those concerned with new applications and data on isotope geochemistry and isotopic dating. Several papers will concentrate on diffusion of oxygen and strontium. New applications and interpretation of Rb-Sr and Ar-40/Ar-39 dating, new data on U and Pb isotopic variations in single crystals, and further developments in Re-187/0S187 chronometry will also be topics of discussion. (Wednesday, P.M.)

Volcanoes and Their Rocks

Two half-day sessions are devoted to the description of circum-Pacific and Pacific volcanoes, eruption mechanisms, and the geochemistry of volcanic eruption products from both oceanic and continental environments. Specific topics range from the mechanism of the 1980 eruption of Mt. St. Helens, through descriptions of volcanic centers in Alaska, Guatemala, New Zealand, and Hawaii, to the geochemistry continental lavas from North America, Africa, and India. Those interested in magma mixing and magma chambers will also find food for thought. (Thursday)

Neat Papers About Plutonic Rocks

The session focuses primarily on the geochemistry and petrology of granites and granitic rocks from the eastern part of North America. Petrologists interested in the origin of tonalites, nepheline syenites, and gabbros, however, will not be disappointed. (Friday, A.M.)

VGP Potpourri

Among the diverse subjects covered in this session will be new evidence from New Mexico on the Iridium anomaly at the Cretaceous-Tertiary boundary and the extinction of dinosaurs. Also included are a series of papers dealing with the problems of storing nuclear waste in the geologic environment and a paper discussing Nd and Sr isotopic evidence on the origin of central American volcanos. (Friday, A.M.)

Decade of North American Geology

During the 1980's, as a part of its centennial, the Geological Society of America is sponsoring the Decade of North American Geology. One of the principal goals of this project is the creation of a massive synthesis of the geology and geophysics of the North American Plate. This will be accomplished by means of a series of 1:5,000,000 geologic, tectonic, gravity anomaly, magnetic anomaly, and lineament maps, and approximately 23 volumes of integrated information on regional geology and geophysics. The activity will involve most major geological organizations on the continent, and products will appear throughout the decade.

A workshop devoted to discussion of plans for the volumes on the Atlantic Coastal Plain and Shelf, the Western Atlantic Ocean Basin, and the Eastern Pacific Ocean Basin is scheduled for Monday, 3–5 P.M., Room 318.

GAP

Electromagnetics

0785 Tropospheric propagation
ANALYSIS OF SHORT-TERM STATISTICAL VARIATIONS IN RAIN DEPOLARIZATION
J. Kanellopoulos (Department of Electrical Engineering, National Technical University of Athens, 42, October 28th Ave., Athens-147, Greece)

Observed electromagnetic wave depolarization in forward propagation due to precipitation in a short-term period tends to distribute statistically about some mean level of depolarization. Using a special Rayleigh depolarization model, we have analyzed the statistical scatter of the cross-polarization discrimination (XPD) of the received signal and found an approximate normal model with a standard deviation of approximately 4.34 db about the mean, independent of all the parameters of the radio link (Rain depolarization, statistical variations).

Rad. Sci., Paper 1S0534

0785 Tropospheric propagation
ANALYSIS OF LONG-TERM RAIN ATTENUATION STATISTICS
J. Kanellopoulos (Department of Electrical Engineering, National Technical University of Athens, 42 October 28th Ave., Athens-147, Greece) H. Kofolas and N. Androulakis

An experimental verification of Lin's prediction model for rain attenuation statistics with data taken from a terrestrial radio link in Athens, is presented. It provides an encouraging indication that this model could be the appropriate one for radio paths in the Greek airspace (Rain attenuation, statistics, prediction modoll).

Rad. Sci., Paper 1S0535

0785 Tropospheric propagation
JOINT STATISTICS ANALYSIS BETWEEN RAIN DEPOLARIZATION AND ATTENUATION
J. Kanellopoulos (Department of Electrical Engineering, 42, October 28th Ave., Athens-147, Greece) A. Kontonasios.

A direct formulation of joint statistics between rain attenuation and cross-polarization discrimination (XPD) is proposed. The results of the model agree well with existing experimental data concerning the performance of radio links, as well as with previous two-dimensional normal approaches (Rain attenuation, depolarization, fade outage time).

Rad. Sci., Paper 1S0533

Exploration Geophysics

0930 Seismic methods
THREE-DIMENSIONAL VELOCITY PROFILE INVERSION FROM FINITE-OFFSET SCATTERING DATA
0910 Computer applications
S. Raz (The Technion—Israel Institute of Technology, Department of Electrical Engineering, Technion City, Haifa 32 000, Israel)

The reconstruction of three-dimensional (3-D) velocity variations from finite-offset scattering data is formulated. Reduction to the limiting cases of zero and small offset distances as well as the case of one-dimensional (1-D) stratification is given. An inherent increase in complexity is cited and interpreted. The relationship of the proposed inversion to the F-K migration is discussed.

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0930 Seismic methods
SYNTHETIC VERTICAL SEISMIC PROFILE
K. Dautenhahn Wyatt (Phillips Petroleum Company, 71-C PRC, Bartlesville, OK 74004)

A time-domain model has been developed for calculation of a synthetic vertical seismic profile (SVSP) from a sonic log recorded in a borehole. The SVSP has proven to be extremely useful in the interpretation of seismic data since it allows the interpreter to analyze the propagation of the source pulse through the earth in depth as well as time.

Previously, the synthetic seismogram technique allowed analysis of the earth's response to the source pulse at the surface only. However, the development of the SVSP allows insight into the entire wave propagation problem since the calculation shows the response of the earth to the source pulse at any depth point in the subsurface. For example, the synthetic seismogram can be used to identify an event on the seismic section as a multiple, whereas, the SVSP cannot only identify a multiple, but can also show which path the source pulse took through the earth layers to create the multiple.

The SVSP can also be used to analyze the change in character of the source pulse due to the layering effect of the earth, for example, effects of a thin bed sequence; to study amplitude variations due to transmission losses; and to examine the effects of different source pulse bandwiths on the final surface seismogram, etc. As interpreters gain experience in analyzing the SVSP, many more applications are expected to appear.

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0930 Seismic methods
THE THEORETICAL SEISMIC REFLECTION RESPONSE OF SEDIMENTARY SEQUENCES
See 0910 Computer applications
C. J. Volseboer (Shell Development Company, Bellaire Research Center, P. O. Box 481, Houston, TX 77001)

A sedimentary sequence can quite often be considered very fruitfully as a discrete Markov chain, and thus can be described by a stochastic matrix. Knowing this matrix and the thickness probability distributions of the layers of the various participating lithologies, while assuming that their densities and velocities are normally distributed, and expression is derived for the autocorrelation (or power spectrum) of the seismic reflection response. This expression can bring out essential characteristics of the power spectra, i.e., the low-frequency droop and its slope. This then leads to the possible estimation of some physical and sedimentary parameters of the sequence such as the scatter of the reflection coefficients and the sand-shale ratio or sedimentary cycle thickness.

The case of a binary sequence, as the predominant sequence of the sediments of the Gulf Coast area and Nigeria, is analysed in detail. The theoretical results conform well with field data and lead to the interesting conclusion that indeed the estimation of the above mentioned parameters is possible.

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0930 Seismic methods
AN EXAMINATION OF TUBE NOISE IN VERTICAL SEISMIC PROFILING DATA
B. A. Hardage (Phillips Petroleum Company, 71-C PRC, Bartlesville, OK 74004)

Tube waves act as noise that camouflages upgoing and downgoing body wave events which are the fundamental seismic data measured in vertical seismic profiling (VSP). In two onshore vertical seismic profiles, the principal source of tube waves is shown to be surface ground roll that sweeps across the well head. Secondary tube wave sources revealed in these VSP data are the downhole geophone tool itself and the bottom of the borehole. Body wave signals are also shown to create tube waves when they arrive at significant impedance contrasts in the borehole such as changes in casing diameter.

Computer simulated vertical geophone arrays are used to reduce these tube waves, but such arrays attenuate and filter body wave events unless static time shifts are made so that the body wave signal occurs at the same two-way time at each geophone station. Consequently, actual downhole vertical geophone arrays are not an effective means by which tube waves can be eliminated. Power spectra comparisons of tube wave and compressional body wave events demonstrate that band-pass filters designed to eliminate tube waves also suppress body wave signals. A simple but effective field technique for reducing tube waves is shown to be proper source offset.

Using velocity filters to retrieve upgoing compressional events from VSP data heavily contaminated with tube wave noise yields in one example an agreement with surface measured reflections that is superior to that obtained from synthetic seismograms calculated from log data recorded in the same well.

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0930 Seismic methods
MODELING OF THE ACOUSTIC WAVE EQUATION WITH TRANSFORM METHODS
See 0910 Computer applications
Jeno Gazdag (IBM Scientific Center, P. O. Box 10500, 1530 Page Mill Road, Palo Alto, CA 94304)

Numerical methods are described for the simulation of wave phenomena with application to the modeling of seismic data. Two separate topics are studied. The first deals with the solution of the acoustic wave equation. The second topic treats wave phenomena whose direction of propagation is restricted within ±90 degrees from a given axis.

In the numerical methods developed here, the wave field is advanced in time by using standard time differencing schemes. On the other hand, expressions including space derivative terms are computed by Fourier transform methods. This approach to computing derivatives minimizes truncation errors. Another benefit of transform methods becomes evident when attempting to restrict propagation to upward moving waves, e.g., to avoid multiple reflections. Constraints imposed on the direction of the wave propagation are accomplished most precisely in the wavenumber domain.

The error analysis of the algorithms shows that truncation errors are due mainly to time discretization. Such errors can be limited by the choice of the time step. Perhaps the most significant error phenomenon is related to aliasing. This becomes noticeable when a narrow pulse traverses a region with strong velocity variations. It is shown that aliasing errors can be limited by the choice of the pulse width. The feasibility of these modeling methods is demonstrated on numerical examples.

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0930 Seismic methods
INVERSION OF REFRACTION DATA BY WAVE FIELD CONTINUATION
See 0910 Computer applications
Robert W. Clayton (Stanford Exploration Project, Department of Geophysics, Stanford University, Stanford, CA 94305) George A. McMechan

The process of wave equation continuation (migration) is adapted for refraction data in order to produce velocity-depth models directly from the recorded data. The procedure consists of two linear transformations: a slant stack of the data produces a wave field in the p – τ plane which is then downward continued using τ = 0 as the imaging condition. The result is that the data wave field is linearly transformed from the time-distance domain into the slowness-depth domain, where the velocity profile can be picked directly. No travel-time picking is involved, and all the data are present throughout the inversion.

The method is iterative because it is necessary to specify a velocity function for the continuation. The solution produced by a given iteration is used as the continuation velocity function for the next step. Convergence is determined when the output wave field images the same velocity-depth function as was input to the continuation.

The method obviates the problems associated with determining the envelope of solutions that are consistent with the observations, since the time resolution in the data is transformed into a depth resolution in the slowness-depth domain.

The method is illustrated with several synthetic examples, and with a refraction line recorded in the Imperial Valley, California.

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0930 Seismic methods
FUNDAMENTALS OF FREQUENCY DOMAIN MIGRATION
Joong H. Chun (Seismograph Service Corp., P. O. Box 1590, Tulsa, OK 74102) Chester A. Jacewitz

Frequency domain migration is founded upon the wave equation, and so includes diffractions and other effects. This paper seeks to motivate and illuminate frequency domain migration using straightforward geometric techniques and simple frequency domain observations.

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